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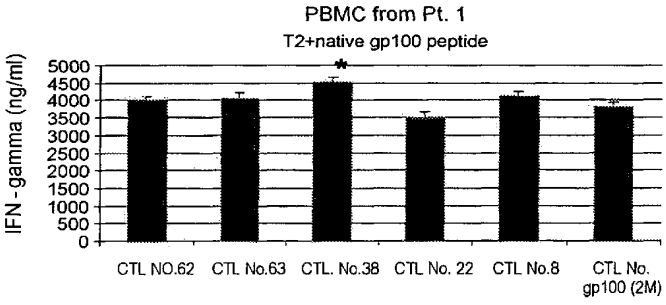
(54) Title: CANCER VACCINES AND VACCINATION METHODS

(57) Abstract: Methods and compositions for treating cancers (e.g., neural cancers) by dendritic cell vaccination are provided herein.



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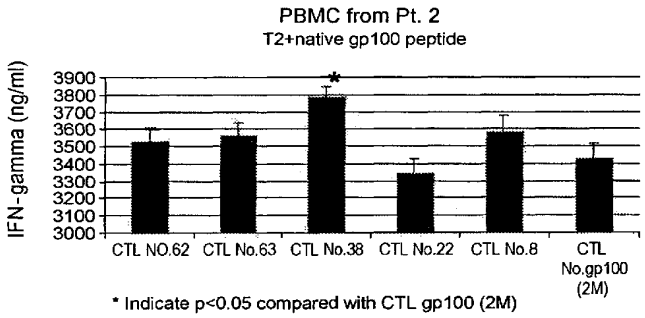

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CANCER VACCINES AND VACCINATION METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of priority from U.S. Provisional Patent Application Serial No. 60/827,260, filed on September 28, 2006, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

The invention relates to methods and compositions for the treatment of cancers, such as neural cancers.

BACKGROUND

Brainstem gliomas are a heterogeneous group of tumors that can be distinguished by age of onset, clinical and radiological presentation, and biological behavior. The diagnosis of a diffuse brainstem glioma is based upon typical imaging, dispensing with the need for surgery in the majority of cases. Radiation therapy is the mainstay of treatment for children with diffuse brainstem gliomas. The role of chemotherapy for these children is not clear, and it is, in general, employed in the context of an investigational study. Less than 10% of children with diffuse brainstem gliomas survive 2 years. In contrast to childhood brainstem gliomas, adult brainstem gliomas are rare and poorly understood. Mean age at onset is 34 years. The main presenting symptoms are gait disturbance (61%), headache (44%), weakness of the limbs (42%) and diplopia (40%). The diagnosis of a brainstem glioma is uniformly lethal. Glioblastoma is the most common and most malignant primary brain tumor. Survival with surgery, radiation, and chemotherapy ranges from 12 to 15 months.

The potential therapy is immunotherapy, which is a form of cancer treatment that activates the immune system to attack and eradicate cancer cells. Cytotoxic T lymphocytes ("CTL") are critical to a successful antitumor immune response. T cells that attack cancer cells require the presentation of tumor antigens to naïve T cells that undergo activation, clonal expansion, and ultimately exert their cytolytic effector function. Unfortunately, this mechanism is defective in patients with malignant gliomas. Effective antigen presentation is essential to successful CTL effector function. Thus, the development of a successful strategy to initiate presentation of tumor antigens to T cells

can be important to an immunotherapeutic strategy for malignant brain tumors (Liu et al., Expert Rev. Vaccines, 5(2):233-247, 2006).

Various immunotherapies have been investigated for malignant glioma, including antibody- and cytokine-based therapies, cancer vaccines, and adoptive cellular therapies. However, such treatments for central nervous system gliomas have not been discovered as quickly as therapies for more immunogenic tumors, e.g., melanoma. This is partly due to the relative lack of defined glioma-associated antigens that can be targeted by the immune system. In recent years, several tumor-associated antigens ("TAA") have been identified and characterized for different cancers, including breast, colon, renal, and melanoma.

Some tumor-associated antigens have been identified for human glioma cells, including tyrosinase-related protein (TRP)-2 (a melanoma differentiation antigen), Melanoma-associated Antigen-1 (MAGE-1), a cancer/testis antigen, HER-2/neu (selectively overexpressed in tumors), interleukin-13 (IL-13) receptor α2, gp100 (a melanoma differentiation antigen), and Antigen isolated from Immunoselected Melanoma-2 (AIM-2), a novel tumor antigen (Liu et al., Oncogene, 24(33): 5226-5234, 2005; Liu et al., J. Immunother., 26(4): 301-312, 2003; Liu et al., J. Immunother., 27(3): 220-226, 2004; Liu et al., Canc. Res., 64: 4980-4986, 2004).

With respect to these specific antigens, a vaccine consisting of dendritic cells pulsed with MAGE-1 peptide has been used in melanoma patients to induce clinical and systemic tumor-specific responses without provoking major side effects. It has also been shown that melanoma patients immunized with a melanoma cell vaccine induce antibody responses to recombinant MAGE-1 antigen. In addition, several clinical trials have indicated that gp100 is a highly immunogenic antigen in melanoma patients, and showed a strong correlation between T cell recognition of the gp100 antigen and clinical responses. The HER-2 oncogenic protein has been well-defined in the art, and a HER-2 specific vaccine has been tested in human clinical trials. Early results showed the immunity elicited by the vaccine was durable even after vaccinations ended.

The immunogenicity and regulation of HER-2, gp100, and MAGE-1 in glioblastoma multiforme ("GBM") have been investigated. Liu et al. (Canc. Res., 64: 4980-4986, 2004) describes that the majority of GBMs express these antigens and process the dominant epitopes. It was also determined that CTLs recognize these antigens on GBMs, and that recognition is determined by both antigen expression and MHC expression on the cell surfaces. These results showed that tumor antigen expression in GBM cells correlates with tumor cell recognition by CTLs.

With respect to the antigen AIM-2, it has been shown that both non-spliced and spliced AIM-2 transcripts are expressed in many tumor types. One particular melanoma-reactive T cell clone recognizes a peptide from non-spliced AIM-2, but not from spliced AIM-2. GBMs express AIM-2 – spliced and non-spliced forms – and process the dominant epitope from non-spliced AIM-2, allowing CTL recognition of peptides. In addition, AIM-2 CTL have been generated in certain patients by vaccination with dendritic cells pulsed with tumor lysates, and that the ability of CTLs to recognize autologous tumor cells was increased by these vaccinations.

TRP-2 is a naturally processed, immunogenic tumor antigen in mice and humans. Vaccination with dendritic cells pulsed with TRP-2 has been shown to generate TRP-2-specific CTLs and immunity against B16 melanoma tumors, delay B16 tumor growth, and prolong mouse survival. It was also demonstrated that immunization with the human TRP-2 gene elicited autoantibodies and autoreactive cytotoxic T cells. TRP-2-specific cytotoxic T cell activity has been detected in patients after vaccination with dendritic cells pulsed with autologous tumor lysate. In a dendritic cell-based phase I clinical trial, TRP-2 peptide-specific CTLs were induced in patients without observed side effects or autoimmune reactions. It has also been demonstrated that GBM cells from postvaccination resections show lower TRP-2 expression and higher sensitivity to chemotherapeutic drugs than autologous cell lines from pre-vaccination resections.

With the diagnosis of a brainstem glioma being uniformly lethal, glioblastoma as the most common and most malignant primary brain tumor, and survival with surgery, radiation, and chemotherapy only ranging from 12 to 15 months, there exists a significant need in the art for the development of novel therapeutic measures.

SUMMARY

The invention is based, in part, on the discovery that immunizing glioma patients with antigen presenting cells (APC) loaded with unique combinations of multiple tumor antigens induces therapeutic immune responses that can be used to treat these patients to provide significantly increased survival. Accordingly, methods for inducing immune responses in cancer patients (e.g., neural cancer patients, such as glioma patients) against tumor antigens are provided herein. The methods use as vaccines APC, such as dendritic cells (DC), that present specific combinations of multiple different tumor antigens. Also provided are compositions that include the cells and the antigens.

Various embodiments provide for vaccines including epitopes of any combination of four or more of the following antigens: tyrosinase-related protein (TRP)-2, Melanoma-associated Antigen-1 (MAGE-1), HER-2, IL-13 receptor α2, gp100, and AIM-2. For example, the vaccines include epitopes (e.g., peptide fragments) of any four of the antigens, any five of the antigens, or all six of the antigens. In some embodiments, the vaccines include epitopes for additional tumor antigens.

Additional embodiments of the present invention provide for vaccines loaded with one or more superagonist epitopes for some or all of the following antigens: TRP-2, MAGE-1, HER-2, IL-13 receptor α2, gp100, and AIM-2. A "superagonist" or "superantigen" peptide is a peptide that includes one or more mutations (e.g., one, two, or three amino acid changes, relative to a native sequence) and that elicits an antigen-specific immunological response that is more potent than a response elicited by a peptide having a native sequence. For example, a superagonist peptide stimulates higher levels of IFN-γ release by antigen-specific T cells, as compared to T cells stimulated with the native peptide. The increase in levels of IFN-γ release stimulated by a superagonist peptide are higher that levels stimulated by a native peptide by a statistically significant amount. In some embodiments, a superagonist stimulates IFN-γ levels that are at least 5%, 10%, 25%, 50%, 100%, 200%, or 500% higher that elicited by the native peptide.

The vaccines of the present invention can be used to treat a cancer, e.g., a neural cancer. In particular embodiments, the vaccines can be used to treat gliomas. In other embodiments the vaccines can be used to treat glioblastoma multiforme (GBM). In other embodiments, the vaccines can be used to treat astrocytomas. In various embodiments, the vaccines are administered in an amount sufficient to induce an immune response against the antigens (e.g., a T cell response).

The vaccines can include autologous dendritic cells. In alternative embodiments, the vaccines can include allogeneic dendritic cells. Dendritic cells suitable for use in the vaccination methods disclosed herein can be isolated or obtained from any tissue in which such cells are found, or can be otherwise cultured and provided. Dendritic cells can be found in, for example, but in no way limited to, the bone marrow, peripheral blood mononuclear cells (PBMCs) of a mammal, or the spleen of a mammal. Additionally, any suitable media that promote the growth of dendritic cells can be used in accordance with the present invention, and can be readily ascertained by one skilled in the art.

The dendritic cells in the vaccines described herein can be pulsed with any or all of the following antigens (i.e., incubated for a sufficient time to allow uptake and presentation of peptides of the antigens on MHC molecules): TRP-2, MAGE-1, HER-2, IL-13 receptor α2, gp100, and AIM-2, or epitopes of these antigens (e.g., peptide epitopes 7-25 amino acids in length). The epitopes are, for example, peptides 7 to 13 (e.g., 8 to 10, e.g., 9) amino acids in length.

The dendritic cells present epitopes corresponding to the antigens at a higher average density than epitopes present on dendritic cells exposed to a tumor lysate (e.g., a neural tumor lysate). The dendritic cells can acquire the antigens or portions thereof (e.g., peptide epitopes) by incubation with the antigens in vitro (e.g., wherein cells acquire antigens by incubation with the combination of the antigens simultaneously, or with a subset of antigens, e.g., in separate pools of cells). In some embodiments, the dendritic cells are incubated with a composition including the peptides, wherein the peptides are synthetic peptides and/or were isolated or purified prior to incubation with the cells. In some embodiments, dendritic cells are engineered to express the peptides by recombinant means (e.g., by introduction of a nucleic acid that encodes the full length antigen or a portion thereof, e.g., the peptide epitope).

In some embodiments, the synthetic peptides include a synthetic peptide having a dibasic motif (i.e., Arg-Arg, Lys-Lys, Arg-Lys, or Lys-Arg) at the N-terminus and a dibasic motif at the C-terminus. In some embodiments, the synthetic peptides include a HER2 peptide including one of the following amino acid sequences: RRILHNGAYSLRR (SEQ ID NO:1) or RRKIFGSLAFLRR (SEQ ID NO:2).

The dendritic cells can include a peptide including an amino acid sequence corresponding to an epitope of TRP-2, MAGE-1, HER-2, IL-13 receptor α2, gp100, and AIM-2, described herein. For example, the dendritic cells include at least one of the following sequences: RSDSGQQARY (SEQ ID NO:3) from AIM-2; EADPTGHSY (SEQ ID NO:4) from MAGE-1; SVYDFFVWL (SEQ ID NO:5) from TRP-2; ITDQVPFSV (SEQ ID NO:6) from gp100; KIFGSLAFL (SEQ ID NO:7) from HER-2; and WLPFGFILI (SEQ ID NO:8) from IL-13 receptor α2. In some embodiments, the peptide is amidated at the C-terminus.

In alternative embodiments, the dendritic cells in the vaccines are pulsed with any or all of superagonist epitopes of some or all of the aforementioned antigens. The superagonist antigens have certain amino acid substitutions that generate a more potent immune response than the natural epitopes. In some embodiments, the dendritic cells are

pulsed with a peptide epitope including one or both of the following superagonist peptide sequences: YMDQVPYSV (SEQ ID NO:65) from gp100; or FMANVAIPHL (SEQ ID NO:68) from HER-2. In some embodiments, the dendritic cells are pulsed with a peptide epitope including one of the following peptide sequences: FLDQVPYSV (SEQ ID NO:63) from gp100; ILDQVPFSV (SEQ ID NO:66) from gp100; IMDQVPFSV (SEQ ID NO:67) from gp100, FMHNVPIPYL (SEQ ID NO:69) from HER-2; or FYANVPSPHL (SEQ ID NO:70) from HER-2. In some embodiments, the peptide is amidated at the C-terminus. Superagonist peptides can be used in combination with any of the peptides described herein. .

In some embodiments, the dendritic cells include more than one peptide epitope for a given antigen, e.g., wherein the dendritic cells comprise two, three, four, or more peptide epitopes from AIM-2, and/or two, three, four, or more peptide epitopes from MAGE-1, and so forth.

Other embodiments of the present invention provide for methods of treating cancers (e.g., neural cancers, e.g., gliomas) using the inventive vaccines. In one embodiment, the method of treating gliomas comprises administering a vaccine as described herein to a patient. Other embodiments provide for methods of treating cancers such as carcinomas, or brain metastatic cancers.

The vaccines can be administered one or more times to a patient to impart beneficial results. The vaccines can be administered prior or post surgical resection of the tumor. One skilled in the art will be able to determine the appropriate timing for administering the vaccine. The timing of the first and/or subsequent dose(s) of the vaccine can depend on a variety of factors, including, but not limited to a patient's health, stability, age, and weight. The vaccine can be administered at any appropriate time interval; for example, including but not limited to, once per week, once every two weeks, once every three weeks, once per month. In one embodiment, the vaccine can be administered indefinitely. In one embodiment, the vaccine can be administered three times in two week intervals. Appropriate dosages of the vaccines also depends on a variety of factors, including, but not limited to, a patient's health, stability, age, and weight. In one embodiment, the vaccine includes from about 10^5 to about 10^9 tumor antigen-pulsed dendritic cells. In another embodiment, the vaccine includes about 10^7 tumor antigen-pulsed dendritic cells.

In some embodiments, the methods of treating cancers include identifying a patient whose tumor expresses one or more of TRP-2, MAGE-1, HER-2, IL-13 receptor

α2, gp100, and AIM-2, prior to the treatment. For example, a method can include evaluating whether a tumor in a glioma patient expresses HER-2, and, if the tumor expresses HER-2, administering the vaccine to the patient. Patients whose tumors are positive for other tumor antigens can also be identified and selected for treatment.

The vaccines can be administered in conjunction with other therapeutic treatments; for example, chemotherapy and/or radiation. In some embodiments, the inventive vaccines are administered by injection (i.e., intravenous, intraarterial, etc.). In other embodiments, the inventive vaccines are administered directly into or in close proximity of the tumor. In other embodiments, the inventive vaccines are administered directly into or in close proximity of the site of the resected tumor.

In other embodiments, methods of producing the inventive vaccines are provided. In some embodiments, the vaccines are made by obtaining dendritic cells from a subject and loading the dendritic cells with the antigens. The dendritic cells can be autologous or allogeneic.

In some embodiments, a method of producing the vaccine includes obtaining bone marrow derived mononuclear cells from a subject, culturing the mononuclear cells in vitro under conditions in which mononuclear cells become adherent to a culture vessel, selecting a subset of the mononuclear cells including adherent cells, culturing the subset of cells in the presence of one or more cytokines (e.g., GM-CSF, IL-4, TNF-α) under conditions in which the cells differentiate into antigen presenting cells, culturing the adherent cells in the presence of synthetic peptides, the peptides including amino acid sequences corresponding to epitopes of at least four of the following six antigens: TRP-2, MAGE-1, HER-2, IL-13 receptor α2, gp100, and AIM2, under conditions in which the cells present the peptides on major histocompatibility class I molecules, thereby preparing a cell vaccine. In some embodiments, the bone marrow derived cells are obtained from a patient with a cancer (e.g., a neural cancer, e.g., glioma), and the cell vaccine is prepared to treat the patient.

In some embodiments, the synthetic peptides include a synthetic peptide having a dibasic motif (i.e., Arg-Arg, Lys-Lys, Arg-Lys, or Lys-Arg) at the N-terminus and a dibasic motif at the C-terminus. In some embodiments, the synthetic peptides include a HER2 peptide including one of the following amino acid sequences: RRILHNGAYSLRR (SEQ ID NO:1) or RRKIFGSLAFLRR (SEQ ID NO:2).

In another aspect, the invention features a peptide fragments of TRP-2, MAGE-1, IL-13 receptor α2, gp100, and AIM2, modified to include dibasic motifs at the N-terminus and C-terminus (e.g., a peptide having one of the following amino acid sequences: RRRSDSGQQARYRR (SEQ ID NO:9); RREADPTGHSYRR (SEQ ID NO:10); RRSVYDFFVWLRR (SEQ ID NO:11); RRITDQVPFSVRR (SEQ ID NO:12); and RRWLPFGFILIRR (SEQ ID NO:13). Combinations of the peptides, and compositions including the peptides are also provided.

This invention also provides immunogenic compositions that include, or encode the combinations of antigens described herein, and methods of using the compositions. For example, preparations of HER-2, AIM-2, MAGE-1, TRP-2, IL-13 receptor α2, and gp100 peptides, for use as cancer vaccines (e.g., peptide vaccines, or nucleic acids encoding the peptides) are provided. The invention also provides immunogenic compositions that include a superagonist peptide, e.g., a superagonist peptide epitope corresponding to one or more of HER-2, AIM-2, MAGE-1, TRP-2, IL-13 receptor α2, and gp100.

"Beneficial results" can include, but are in no way limited to, lessening or alleviating the severity of the disease condition, preventing the disease condition from worsening, curing the disease condition, and prolonging a patient's life or life expectancy.

"Cancer" and "cancerous" refer to or describe the physiological condition in mammals that is typically characterized by unregulated cell growth. Examples of neural cancers include cancers of the brain and spinal cord such as gliomas, glioblastomas, glioblastoma multiforme (GBM), oligodendrogliomas, primitive neuroectodermal tumors, low, mid and high grade astrocytomas, ependymomas (e.g., myxopapillary ependymoma papillary ependymoma, subependymoma, anaplastic ependymoma), oligodendrogliomas, medulloblastomas, meningiomas, pituitary adenomas, neuroblastomas, and craniopharyngiomas. GBM, glioblastomas, astrocytomas, ependymomas, and oligodendrogliomas are types of gliomas.

"Conditions" and "disease conditions," as used herein can include, but are in no way limited to any form of neoplastic cell growth and proliferation, whether malignant or benign, pre-cancerous and cancerous cells and tissues; in particular, gliomas, glioblastomas, glioblastoma multiforme (GBM), oligodendrogliomas, primitive neuroectodermal tumors, low, mid and high grade astrocytomas, ependymomas (e.g., myxopapillary ependymoma papillary ependymoma, subependymoma, anaplastic

ependymoma), oligodendrogliomas, medulloblastomas, meningiomas, pituitary adenomas, neuroblastomas, and craniopharyngiomas.

"Mammal" as used herein refers to any member of the class Mammalia, including, without limitation, humans and nonhuman primates such as chimpanzees and other apes and monkey species; farm animals such as cattle, sheep, pigs, goats, and horses; domestic mammals such as dogs and cats; laboratory animals including rodents such as mice, rats, and guinea pigs, and the like. The term does not denote a particular age or sex. Thus, adult and newborn subjects, as well as fetuses, whether male or female, are intended to be included within the scope of this term. The terms "patient" and "subject" are used interchangeably herein, and cover mammals including humans.

"Pathology" of cancer includes all phenomena that compromise the well-being of the patient. This includes, without limitation, abnormal or uncontrollable cell growth, metastasis, interference with the normal functioning of neighboring cells, release of cytokines or other secretory products at abnormal levels, suppression or aggravation of inflammatory or immunological response, neoplasia, premalignancy, malignancy, invasion of surrounding or distant tissues or organs, such as lymph nodes, etc.

"Treatment" and "treating," as used herein refer to both therapeutic treatment and prophylactic or preventative measures, wherein the object is to inhibit or slow down (lessen) the targeted disorder (e.g., cancer, e.g., glioma) or symptom of the disorder, or to improve a symptom, even if the treatment is partial or ultimately unsuccessful. Those in need of treatment include those already diagnosed with the disorder as well as those prone or predisposed to contract the disorder or those in whom the disorder is to be prevented. For example, in tumor (e.g., cancer) treatment, a therapeutic agent can directly decrease the pathology of tumor cells, or render the tumor cells more susceptible to treatment by other therapeutic agents or by the subject's own immune system.

"Tumor," as used herein refers to all neoplastic cell growth and proliferation, whether malignant or benign, and all pre-cancerous and cancerous cells and tissues.

A "dendritic cell" or "DC" is an antigen presenting cell (APC) that typically expresses high levels of MHC molecules and co-stimulatory molecules, and lacks expression of (or has low expression of) markers specific for granulocytes, NK cells, B lymphocytes, and T lymphocytes, but can vary depending on the source of the dendritic cell. DCs are able to initiate antigen specific primary T lymphocyte responses in vitro and in vivo, and direct a strong mixed leukocyte reaction (MLR) compared to peripheral blood leukocytes, splenocytes, B cells and monocytes. Generally, DCs ingest antigen by

phagocytosis or pinocytosis, degrade it, present fragments of the antigen at their surface and secrete cytokines.

Unless defined otherwise, technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Singleton et al., Dictionary of Microbiology and Molecular Biology 3rd ed., J. Wiley & Sons (New York, NY 2001); March, Advanced Organic Chemistry Reactions, Mechanisms and Structure 5th ed., J. Wiley & Sons (New York, NY 2001); Sambrook and Russel, Molecular Cloning: A Laboratory Manual 3rd ed., Cold Spring Harbor Laboratory Press (Cold Spring Harbor, NY 2001); and Lutz et al., Handbook of Dendritic Cells: Biology, Diseases and Therapies, J. Wiley & Sons (New York, NY 2006), provide one skilled in the art with a general guide to many of the terms used in the present application. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, suitable methods and materials are described below. All publications, patent applications, patents, and other references mentioned herein are incorporated by reference in their entirety. In case of conflict, the present specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting.

Other features and advantages of the invention will be apparent from the following detailed description, the drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a graph depicting levels of epitope-specific T cell responses in mice following immunization IV with mouse lysozyme-M (ML-M), a mouse lysozyme peptide (p19-30), and a mouse lysozyme peptide modified with dibasic residues (18R31R), as measured by cell proliferation in vitro. T cells were isolated from lymph nodes of the animals (3 animals per group) and response to each immunogen was measured.

FIGs. 2A and 2B are bar graphs that show IFN-γ levels after in vitro induction of CTL in patient-derived PBMCs with dendritic cells pulsed with gp100(2M) or superagonist gp100 peptides in accordance with an embodiment of the present invention in two separate patients.

FIGs. 3A and 3B are bar graphs that show IFN-γ levels after in vitro induction of CTL in patient-derived PBMCs with native or superagonist Her-2 peptides in accordance with an embodiment of the present invention in two different patients.

FIG. 4 is a bar graph that shows IFN-γ levels produced by CTL after in vitro induction of the CTL in patient-derived PBMCs with native (no. 52) or altered Her-2 peptides (nos. 19, 32, and 41), as measured by ELISA. CTL were cocultured with Her-2 positive, gp100 positive cell lines.

FIG. 5 is a bar graph that shows numbers of IFN-γ positive cells, as measured by ELISPOT analysis of CTL generated against Her-2 peptide nos. 19, 32, 41, and 52. For the ELISPOT assays, CTL were incubated with T2 cells pulsed with a HER-2 native peptide.

FIG. 6 is a bar graph that shows IFN-γ levels produced by CTL after in vitro induction of the CTL in patient-derived PBMCs with a native (no. 2M) or altered gp100 peptides (nos. 8, 22, 38, 62, and 63), as measured by ELISA. CTL were cocultured with Her-2 positive, gp100 positive cell lines.

FIG. 7 is a is a bar graph that shows numbers of IFN-γ positive cells, as measured by ELISPOT analysis of CTL generated against gp100 peptide nos. 2M, 8, 22, 38, 62, and 63. For the ELISPOT assays, CTL were incubated with T2 cells pulsed with a gp100 native peptide.

DETAILED DESCRIPTION

The invention provides, inter alia, methods and compositions for treating gliomas by administering cells presenting unique combinations of tumor antigens. Vaccination with dendritic cells or GM-CSF secreting cells is safe and elicits a cytotoxic T cell response associated with memory T cells with dendritic cells and naïve T cells with GM-CSF (Yu, J.S., Wheeler, C.J., Zeltzer, P.M., et al., Cancer Res, 61: 842-847, 2001). The combinations of antigens described herein elicit therapeutic, tumor-specific immune responses. The combinations of antigens described herein stimulate a more heterogeneous immune response than would be elicited with a single antigen, and thus are particularly beneficial for targeting tumors. For example, a tumor may evolve such that expression of a given tumor antigen is turned off. Thus, an immune response against multiple tumor antigens is more likely to provide effective therapy in this context, and can provide significant therapeutic benefits for various patient populations. The present compositions and methods feature combinations including epitopes from four, five, or six of the following: TRP-2, MAGE-1, HER-2, IL-13 receptor α2, gp100, and AIM-2.

Tables 1 and 2 lists amino acid sequences of these antigens and peptide epitopes of the antigens.

Tumor Antigens

AIM-2

AIM-2 is expressed in a variety of tumor types, including neuroectodermal tumors, and breast, ovarian and colon carcinomas. Table 1 provides an amino acid sequence of human AIM-2 (also available in GenBank under accession no. AAD51813.1, GI: 5802881).

The following is an exemplary sequence of an AIM-2 HLA epitope: RSDSGQQARY (SEQ ID NO:3)(also shown in Table 2, below). This epitope is encoded by an alternative open reading frame (see Harada et al., J. Immunother., 24(4):323-333, 2001).

GP100

Gp100 is a glycoprotein preferentially expressed in melanocytes. Table 1 provides an amino acid sequence of human gp100 (also available in GenBank under accession no. NP_008859.1, GI: 5902084). Table 2 lists exemplary HLA epitopes from gp100.

HER-2

HER-2 (also known as HER-2/neu, and c-erbB2) is a transmembrane glycoprotein with tyrosine kinase activity. HER-2 is overexpressed in a variety of tumor types.

Table 1 provides an amino acid sequence of human HER-2 (also available in GenBank under accession no. NP_004439.2, GI: 54792096). Table 2 lists exemplary HLA epitopes from HER-2.

IL-13 Receptor α2

IL-13 receptor α2 is a non-signaling component of the multimeric IL-13 receptor. An exemplary human IL-13 receptor α2 amino acid sequence is shown in Table 1 (also available in Genbank under acc. no. NP_000631.1, GI: 10834992).

The following is an exemplary sequence of an IL-13 receptor α2 HLA epitope, corresponding to amino acids 345-354 of the above sequence: WLPFGFILI (SEQ ID NO:8) (also shown in Table 2).

MAGE-1

MAGE-1 is a cancer/testis antigen originally identified in melanoma.

Table 1 provides an amino acid sequence of human MAGE-1 (also available in GenBank under accession no. NP_004979.3, GI: 148276977). Table 2 lists exemplary MAGE-1 HLA peptide epitopes.

TRP-2

TRP-2 is a dopachrome tautomerase involved in melanogenesis (Aroca et al., Biochim Biophys Acta., 1035(3):266-75, 1990). Human TRP-2 shares 84% identity with murine TRP-2 (Yokoyama et a., Biochim. Biophys. Acta., 1217:317-321, 1994). TRP-2 has five isoforms generated by alternative poly(A) site usage or alternative splicing, including the isoforms designated as TRP-2-6b, TRP-2-INT2, TRP-2-LT, and TRP-2-8b. See Liu et al., J. Immunother., 26(4):301-312, 2003; Pisarra et al., J. Invest. Dermatol., 115:48-56, 2000; Khong and Rosenberg, J. Immunol., 168:951-956, 2002; and Lupetti et al., J. Exp. Med., 188:1005-1016, 1998. Epitopes of each of these isoforms are useful for the vaccines and methods disclosed herein.

Table 1 provides a sequence of human TRP-2 which has 519 amino acids (also available in GenBank under accession no. NP_001913.2, GI:6041667). The amino acid sequence of another human TRP-2 isoform that has 552 amino acids is available in Genbank under acc. no. ABI73976.1, GI:114384149. Table 2 lists exemplary TRP-2 HLA epitopes.

Table 1

Tumor antigen	Amino acid sequence
AIM-2	MVVLGMQTEEGHCIMLRGLAPSLGGTQVICKVVGLPSSIGFNTSSHLLFPATLQGAPTHFPCRWRQGGST DNPPA (SEQ ID NO:14)
gp100	MDLVLKRCLLHLAVIGALLAVGATKVPRNQDWLGVSRQLRTKAWNRQLYPEWTEAQRLDCWRGGQVSLKV SNDGPTLIGANASFSIALNFPGSQKVLPDGQVIWVNNTIINGSQVWGGQPVYPQETDDACIFPDGGPCPS GSWSQKRSFVYVWKTWGQYWQVLGGPVSGLSIGTGRAMLGTHTMEVTVYHRRGSRSYVPLAHSSSAFTIT DQVPFSVSVSQLRALDGGNKHFLRNQPLTFALQLHDPSGYLAEADLSYTWDFGDSSGTLISRALVVTHTY LEPGPVTAQVVLQAAIPLTSCGSSPVPGTTDGHRPTAEAPNTTAGQVPTTEVVGTTPGQAPTAEPSGTTS VQVPTTEVISTAPVQMPTAESTGMTPEKVPVSEVMGTTLAEMSTPEATGMTPAEVSIVVLSGTTAAQVTT TEWVETTARELPIPEPEGPDASSIMSTESITGSLGPLLDGTATLRLVKRQVPLDCVLYRYGSFSVTLDIV QGIESAEILQAVPSGEGDAFELTVSCQGGLPKEACMEISSPGCQPPAQRLCQPVLPSPACQLVLHQILKG GSGTYCLNVSLADTNSLAVVSTQLIMPGQEAGLGQVPLIVGILLVLMAVVLASLIYRRRLMKQDFSVPQL PHSSSHWLRLPRIFCSCPIGENSPLLSGQQV (SEQ ID NO:15)
HER-2	MELAALCRWGLLLALLPPGAASTQVCTGTDMKLRLPASPETHLDMLRHLYQGCQVVQGNLELTYLPTNAS LSFLQDIQEVQGYVLIAHNQVRQVPLQRLRIVRGTQLFEDNYALAVLDNGDPLNNTTPVTGASPGGLREL QLRSLTEILKGGVLIQRNPQLCYQDTILWKDIFHKNNQLALTLIDTNRSRACHPCSPMCKGSRCWGESSE DCQSLTRTVCAGGCARCKGPLPTDCCHEQCAAGCTGPKHSDCLACLHFNHSGICELHCPALVTYNTDTFE SMPNPEGRYTFGASCVTACPYNYLSTDVGSCTLVCPLHNQEVTAEDGTQRCEKCSKPCARVCYGLGMEHL REVRAVTSANIQEFAGCKKIFGSLAFLPESFDGDPASNTAPLQPEQLQVFETLEEITGYLYISAWPDSLP DLSVFQNLQVIRGRILHNGAYSLTLQGLGISWLGLRSLRELGSGLALIHHNTHLCFVHTVPWDQLFRNPH QALLHTANRPEDECVGEGLACHQLCARGHCWGPGPTQCVNCSQFLRGQECVEECRVLQGLPREYVNARHC LPCHPECQPQNGSVTCFGPEADQCVACAHYKDPPFCVARCPSGVKPDLSYMPIWKFPDEEGACQPCPINC

	THSCVDLDDKGCPAEQRASPLTSIISAVVGILLVVVLGVVFGILIKRRQQKIRKYTMRRLLQETELVEPL TPSGAMPNQAQMRILKETELRKVKVLGSGAFGTVYKGIWIPDGENVKIPVAIKVLRENTSPKANKEILDE AYVMAGVGSPYVSRLLGICLTSTVQLVTQLMPYGCLLDHVRENRGRLGSQDLLNWCMQIAKGMSYLEDVR LVHRDLAARNVLVKSPNHVKITDFGLARLLDIDETEYHADGGKVPIKWMALESILRRRFTHQSDVWSYGV TVWELMTFGAKPYDGIPAREIPDLLEKGERLPQPPICTIDVYMIMVKCWMIDSECRPRFRELVSEFSRMA RDPQRFVVIQNEDLGPASPLDSTFYRSLLEDDDMGDLVDAEEYLVPQQGFFCPDPAPGAGGMVHHRHRSS STRSGGGDLTLGLEPSEEEAPRSPLAPSEGAGSDVFDGDLGMGAAKGLQSLPTHDPSPLQRYSEDPTVPL PSETDGYVAPLTCSPQPEYVNQPDVRPQPPSPREGPLPAARPAGATLERPKTLSPGKNGVVKDVFAFGGA VENPEYLTPQGGAAPQPHPPPAFSPAFDNLYYWDQDPPERGAPPSTFKGTPTAENPEYLGLDVPV (SEQ ID NO:16)
IL-13 receptor α2	MAFVCLAIGCLYTFLISTTFGCTSSSDTEIKVNPPQDFEIVDPGYLGYLYLQWQPPLSLDHFKECTVEYE LKYRNIGSETWKTIITKNLHYKDGFDLNKGIEAKIHTLLPWQCTNGSEVQSSWAETTYWISPQGIPETKV QDMDCVYYNWQYLLCSWKPGIGVLLDTNYNLFYWYEGLDHALQCVDYIKADGQNIGCRFPYLEASDYKDF YICVNGSSENKPIRSSYFTFQLQNIVKPLPPVYLTFTRESSCEIKLKWSIPLGPIPARCFDYEIEIREDD TTLVTATVENETYTLKTTNETRQLCFVVRSKVNIYCSDDGIWSEWSDKQCWEGEDLSKKTLLRFWLPFGF ILILVIFVTGLLLRKPNTYPKMIPEFFCDT (SEQ ID NO:17)
MAGE-1	MSLEQRSLHCKPEEALEAQQEALGLVCVQAATSSSSPLVLGTLEEVPTAGSTDPPQSPQGASAFPTTINF TRQRQPSEGSSSREEEGPSTSCILESLFRAVITKKVADLVGFLLLKYRAREPVTKAEMLESVIKNYKHCF PEIFGKASESLQLVFGIDVKEADPTGHSYVLVTCLGLSYDGLLGDNQIMPKTGFLIIVLVMIAMEGGHAP EEEIWEELSVMEVYDGREHSAYGEPRKLLTQDLVQEKYLEYRQVPDSDPARYEFLWGPRALAETSYVKVL EYVIKVSARVRFFFPSLREAALREEEEGV (SEQ ID NO:18)
TRP-2	MSPLWWGFLLSCLGCKILPGAQGQFPRVCMTVDSLVNKECCPRLGAESANVCGSQQGRGQCTEVRADTRP WSGPYILRNQDDRELWPRKFFHRTCKCTGNFAGYNCGDCKFGWTGPNCERKKPPVIRQNIHSLSPQEREQ FLGALDLAKKRVHPDYVITTQHWLGLLGPNGTQPQFANCSVYDFFVWLHYYSVRDTLLGPGRPYRAIDFS HQGPAFVTWHRYHLLCLERDLQRLIGNESFALPYWNFATGRNECDVCTDQLFGAARPDDPTLISRNSRFS SWETVCDSLDDYNHLVTLCNGTYEGLLRRNQMGRNSMKLPTLKDIRDCLSLQKFDNPPFFQNSTFSFRNA LEGFDKADGTLDSQVMSLHNLVHSFLNGTNALPHSAANDPIFVVLHSFTDAIFDEWMKRFNPPADAWPQE LAPIGHNRMYNMVPFFPPVTNEELFLTSDQLGYSYAIDLPVSVEETPGWPTTLLVVMGTLVALVGLFVLL AFLQYRRLRKGYTPLMETHLSSKRYTEEA (SEQ ID NO:19)

Table 2. Tumor Antigen Peptides

Tumor antigen	Position in sequence	Peptide sequence
AIM-2		RSDSGQQARY (SEQ ID NO:3)
gp100	71-78	SNDGPTLI (SEQ ID NO:20)
gp100	154-162	KTWGQYWQV (SEQ ID NO:21)
gp100	209-217	ITDQVPFSV (SEQ ID NO:6)
gp100	280-288	YLEPGPVTA (SEQ ID NO:22)
gp100	613–622	SLIYRRRLMK (SEQ ID NO:23)
gp100	614–622	LIYRRRLMK (SEQ ID NO:24)
gp100	619–627	RLMKQDFSV (SEQ ID NO:25)
gp100	639–647	RLPRIFCSC (SEQ ID NO:26)
gp100	476-485	VLYRYGSFSV (SEQ ID NO:27)

HER-2	5–13	ALCRWGLLL (SEQ ID NO:28)
HER-2	8–16	RWGLLLALL (SEQ ID NO:29)
HER-2	63–71	TYLPTNASL (SEQ ID NO:30)
HER-2	106–114	QLFEDNYAL (SEQ ID NO:31)
HER-2	369–377	KIFGSLAFL (SEQ ID NO:7)
HER-2	435–443	ILHNGAYSL (SEQ ID NO:32)
HER-2	654–662	IISAVVGIL (SEQ ID NO:33)
HER-2	665–673	VVLGVVFGI (SEQ ID NO:34)
HER-2	689–697	RLLQETELV (SEQ ID NO:35)
HER-2	754–762	VLRENTSPK (SEQ ID NO:36)
HER-2	773–782	VMAGVGSPYV (SEQ ID NO:37)
HER-2	780–788	PYVSRLLGI (SEQ ID NO:38)
HER-2	789–797	CLTSTVQLV (SEQ ID NO:39)
HER-2	799–807	QLMPYGCLL (SEQ ID NO:40)
HER-2	835–842	YLEDVRLV (SEQ ID NO:41)
HER-2	851–859	VLVKSPNHV (SEQ ID NO:42)
HER-2	883–899	KVPIKWMALESILRRRF (SEQ ID NO:43)
HER-2	952–961	YMIMVKCWMI (SEQ ID NO:44)
HER-2	971–979	ELVSEFSRM (SEQ ID NO:45)
IL-13 receptor α2	345-354	WLPFGFILI (SEQ ID NO:8)
MAGE-1	102-112	ITKKVADLVGF (SEQ ID NO:46)
MAGE-1	135-143	NYKHCFPEI (SEQ ID NO:47)
MAGE-1	160-169	KEADPTGHSY (SEQ ID NO:48)
MAGE-1	161-169	EADPTGHSY (SEQ ID NO:4)
MAGE-1	230-238	SAYGEPRKL (SEQ ID NO:49)
MAGE-1	278-286	KVLEYVIKV (SEQ ID NO:50)
TRP-2	180-188	SVYDFFVWL (SEQ ID NO:5)
TRP-2	197-205	LLGPGRPYR (SEQ ID NO:51)
TRP-2	222-231(TRP-2-int2 isoform)	EVISCKLIKR (SEQ ID NO:52)
TRP-2	288-296	SLDDYNHLV (SEQ ID NO:53)
TRP-2	360-368	TLDSQVMSL (SEQ ID NO:54)

TRP-2	387-395	ANDPIFVVL (SEQ ID NO:55)
TRP-2	399–407	LLYNATTNI (SEQ ID NO:56)
TRP-2	403–411	ATTNILEHY (SEQ ID NO:57)
TRP-2	402–411	NATTNILEHV (SEQ ID NO:58)
TRP-2	455-463	YAIDLPVSV (SEQ ID NO:59)

Antigenic peptides useful for loading DCs for vaccination are peptides that stimulate a T cell mediated immune response (e.g., a cytotoxic T cell response) by presentation to T cells on MHC molecules. Therefore, useful peptide epitopes of TRP-2, MAGE-1, gp100, AIM-2, IL-3 receptor α2, and HER-2, include portions of the amino acid sequences that bind to MHC molecules and are presented to T cells. Peptides that bind to MHC class I molecules are generally 8-10 amino acids in length. Peptides that bind to MHC class II molecules are generally 13 amino acids or longer (e.g., 13-17 amino acids long).

T cell epitopes can be identified by a number of different methods. Naturally processed MHC epitopes can be identified by mass spectrophotometric analysis of peptides eluted from antigen-loaded APC (e.g., APC that have taken up antigen, or that have been engineered to produce the protein intracellularly). After incubation at 37°C, cells are lysed in detergent and the MHC protein is purified (e.g., by affinity chromatography). Treatment of the purified MHC with a suitable chemical medium (e.g., under acidic conditions, e.g., by boiling in 10% acetic acid, as described in Sanchez et al., 94(9): 4626–4630, 1997) results in the elution of peptides from the MHC. This pool of peptides is separated and the profile compared with peptides from control APC treated in the same way. The peaks unique to the protein expressing/fed cells are analyzed (for example by mass spectrometry) and the peptide fragments identified. This protocol identifies peptides generated from a particular antigen by antigen processing, and provides a straightforward means of isolating these antigens.

Alternatively, epitopes are identified by screening a synthetic library of peptides which overlap and span the length of the antigen in an in vitro assay. For example, peptides which are 9 amino acids in length and which overlap by 5 amino acids may be used. The peptides are tested in an antigen presentation system that includes antigen presenting cells and T cells. T cell activation in the presence of APCs presenting the peptide can be measured (e.g., by measuring T cell proliferation or cytokine production)

and compared to controls, to determine whether a particular epitope is recognized by the T cells.

The peptides can be modified to increase immunogenicity. For example, addition of dibasic amino acid residues (e.g., Arg-Arg, Arg-Lys, Lys-Arg, or Lys-Lys) to the N- and C-termini of peptides can render the peptides more potent immunogens.

The peptides can also include internal mutations that render them "superantigens" or "superagonists" for T cell stimulation. Superantigen peptides can be generated by screening T cells with a positional scanning synthetic peptide combinatorial library (PS-CSL) as described in Pinilla et al. Biotechniques, 13(6):901-5, 1992; Borras et al., J Immunol. Methods, 267(1):79-97, 2002; U.S. Publication No. 2004/0072246; and Lustgarten et al.., J. Immun. 176:1796-1805, 2006. In some embodiments, a superagonist peptide is a peptide shown in Table 2, above, with one, two or three amino acid substitutions which render the peptide a more potent immunogen.

Antigenic peptides can be obtained by chemical synthesis using a commercially available automated peptide synthesizer. Chemically synthesized peptides can be precipitated and further purified, for example by high performance liquid chromatography (HPLC). Alternatively, the peptides can be obtained by recombinant methods using host cell and vector expression systems. "Synthetic peptides" includes peptides obtained by chemical synthesis in vitro as well as peptides obtained by recombinant expression. When tumor antigen peptides are obtained synthetically, they can be incubated with dendritic cells in higher concentrations (e.g., higher concentrations than would be present in a tumor antigen cell lysates, which includes an abundance of peptides from non-immunogenic, normal cellular proteins). This permits higher levels of MHC-mediated presentation of the tumor antigen peptide of interest and induction of a more potent and specific immune response, and one less likely to cause undesirable autoimmune reactivity against healthy non-cancerous cells.

Preparation of Antigen Presenting Cells

Antigen presenting cells (APC), such as dendritic cells (DC), suitable for administration to subjects (e.g., glioma patients) may be isolated or obtained from any tissue in which such cells are found, or may be otherwise cultured and provided. APC (e.g., DC) may be found, by way of example, in the bone marrow or PBMCs of a mammal., in the spleen of a mammal or in the skin of a mammal (i.e., Langerhan's cells, which possess certain qualities similar to that of DC, may be found in the skin). For

instance, bone marrow may be harvested from a mammal and cultured in a medium that promotes the growth of DC. GM-CSF, IL-4 and/or other cytokines (e.g., TNF-α), growth factors and supplements may be included in this medium. After a suitable amount of time in culture in medium containing appropriate cytokines (e.g., suitable to expand and differentiate the DCs into mature DCs, e.g., 4, 6, 8, 10, 12, or 14 days), clusters of DC cultured in the presence of antigens of interest (e.g., in the presence of peptide epitopes of AIM-2, gp100, HER-2, MAGE-1, and TRP-2, or a combination of at least five of these peptides) and harvested for use in a cancer vaccine using standard techniques. Antigens (e.g., isolated or purified peptides, or synthetic peptides) can be added to cultures at a concentration of 1 μg/ml - 50 μg/ml per antigen, e.g., 2, 5, 10, 20, 30, or 40 μg/ml per antigen.

In one exemplary method of preparing APC, APC are isolated from a subject (e.g., a human) according to the following exemplary procedure. Mononuclear cells are isolated from blood using leukapheresis (e.g., using a COBE Spectra Apheresis System). The mononuclear cells are allowed to become adherent by incubation in tissue culture flasks for 2 hours at 37°C. Nonadherent cells are removed by washing. Adherent cells are cultured in medium supplemented with granulocyte macrophage colony stimulating factor (GM-CSF)(800 units/ml, clinical grade, Immunex, Seattle, WA) and interleukin-4 (IL-4)(500 units/ml, R&D Systems, Minneapolis, MN) for five days. On day five, TNF-α is added to the culture medium for another 3-4 days. On day 8 or 9, cells are harvested and washed, and incubated with peptide antigens for 16-20 hours on a tissue rotator. Peptide antigens are added to the cultures at a concentration of ~ 10 μg/ml (per antigen).

Various other methods may be used to isolate the APCs, as would be recognized by one of skill in the art. DCs occur in low numbers in all tissues in which they reside, making isolation and enrichment of DCs a requirement. Any of a number of procedures entailing repetitive density gradient separation, fluorescence activated cell sorting techniques, positive selection, negative selection, or a combination thereof are routinely used to obtain enriched populations of isolated DCs. Guidance on such methods for isolating DCs can be found in O'Doherty, U. et al., J. Exp. Med., 178: 1067-1078, 1993; Young and Steinman, J. Exp. Med., 171: 1315-1332, 1990; Freudenthal and Steinman, Proc. Nat. Acad. Sci. USA, 57: 7698-7702, 1990; Macatonia et al., Immunol., 67: 285-289, 1989; Markowicz and Engleman, J. Clin. Invest., 85: 955-961, 1990; Mehta-Damani et al., J. Immunol., 153: 996-1003, 1994; and Thomas et al., J. Immunol., 151: 6840-

6852, 1993. One method for isolating DCs from human peripheral blood is described in U. S. Patent No. 5,643,786.

The dendritic cells prepared according to methods described herein present epitopes corresponding to the antigens at a higher average density than epitopes present on dendritic cells exposed to a tumor lysate (e.g., a neural tumor lysate). The relative density of one or more antigens on antigen presenting cells can be determined by both indirect and direct means. Primary immune response of naïve animals are roughly proportional to antigen density of antigen presenting cells (Bullock et al., J. Immunol., 170:1822–1829, 2003). Relative antigen density between two populations of antigen presenting cells can therefore be estimated by immunizing an animal with each population, isolating B or T cells, and monitoring the specific immune response against the specific antigen by, e.g., tetramer assays, ELISPOT, or quantitative PCR.

Relative antigen density can also be measured directly. In one method, the antigen presenting cells are stained with an antibody that binds specifically to the MHC-antigen complex, and the cells are then analyzed to determine the relative amount of antibody binding to each cell (see, e.g., Gonzalez et al., Proc. Natl. Acad. Sci. USA, 102:4824-4829, 2005). Exemplary methods to analyze antibody binding include flow cytometry and fluorescence activated cell sorting. The results of the analysis can be reported e.g., as the proportion of cells that are positive for staining for an individual MHC-antigen complex or the average relative amount of staining per cell. In some embodiments, a histogram of relative amount of staining per cell can be created.

In some embodiments, antigen density can be measured directly by direct analysis of the peptides bound to MHC, e.g., by mass spectrometry (see, e.g., Purcell and Gorman, Mol. Cell. Proteomics, 3:193-208, 2004). Typically, MHC-bound peptides are isolated by one of several methods. In one method, cell lysates of antigen presenting cells are analyzed, often following ultrafiltration to enrich for small peptides (see, e.g., Falk et al., J. Exp. Med., 174:425-434, 1991; Rotzxhke et al., Nature, 348:252-254, 1990). In another method, MHC-bound peptides are isolated directly fro the cell surface, e.g., by acid elution (see, e.g., Storkus et al., J. Immunother., 14:94-103, 1993; Storkus et al., J. Immunol., 151:3719-27, 1993). In another method, MHC-peptide complexes are immunoaffinity purified from antigen presenting cell lysates, and the MHC-bound peptides are then eluted by acid treatment (see, e.g., Falk et al., Nature, 351:290-296). Following isolation of MHC-bound peptides, the peptides are then analyzed by mass spectrometry, often following a separation step (e.g., liquid chromatography, capillary gel

electrophoresis, or two-dimensional gel electrophoresis). The individual peptide antigens can be both identified and quantified using mass spectrometry to determine the relative average proportion of each antigen in a population of antigen presenting cells. In some methods, the relative amounts of a peptide in two populations of antigen presenting cells are compared using stable isotope labeling of one population, followed by mass spectrometry (see Lemmel et al., Nat. Biotechnol., 22:450-454, 2004).

Administration of Antigen Presenting Cells

The APC-based cancer vaccine may be delivered to a patient or test animal by any suitable delivery route, which can include injection, infusion, inoculation, direct surgical delivery, or any combination thereof. In some embodiments, the cancer vaccine is administered to a human in the deltoid region or axillary region. For example, the vaccine is administered into the axillary region as an intradermal injection. In other embodiments, the vaccine is administered intravenously.

An appropriate carrier for administering the cells may be selected by one of skill in the art by routine techniques. For example, the pharmaceutical carrier can be a buffered saline solution, e.g., cell culture media, and can include DMSO for preserving cell viability.

The quantity of APC appropriate for administration to a patient as a cancer vaccine to effect the methods of the present invention and the most convenient route of such administration may be based upon a variety of factors, as may the formulation of the vaccine itself. Some of these factors include the physical characteristics of the patient (e.g. , age, weight, and sex), the physical characteristics of the tumor (e.g., location, size, rate of growth, and accessibility), and the extent to which other therapeutic methodologies (e.g., chemotherapy, and beam radiation therapy) are being implemented in connection with an overall treatment regimen. Notwithstanding the variety of factors one should consider in implementing the methods of the present invention to treat a disease condition, a mammal can be administered with from about 10^5 to about 10^8 APC (e.g., 10^7 APC) in from about 0.05 mL to about 2 mL solution (e.g., saline) in a single administration. Additional administrations can be carried out, depending upon the above-described and other factors, such as the severity of tumor pathology. In one embodiment, from about one to about five administrations of about 10^6 APC is performed at two-week intervals.

DC vaccination can be accompanied by other treatments. For example, a patient receiving DC vaccination may also be receiving chemotherapy, radiation, and/or surgical therapy concurrently. Methods of treating cancer using DC vaccination in conjunction with chemotherapy are described in Wheeler et al., US Pat. Pub. No. 2007/0020297. In some embodiments, a patient receiving DC vaccination has already received chemotherapy, radiation, and/or surgical treatment for the cancer. In one embodiment, a patient receiving DC vaccination is treated with a COX-2 inhibitor, as described in Yu and Akasaki, WO 2005/037995.

Immunological Testing

The antigen-specific cellular immune responses of vaccinated subjects can be monitored by a number of different assays, such as tetramer assays, ELISPOT, and quantitative PCR. The following sections provide examples of protocols for detecting responses with these techniques. Additional methods and protocols are available. See e.g., Current Protocols in Immunology, Coligan, J. et al., Eds., (John Wiley & Sons, Inc.; New York, N.Y.).

Tetramer Assay

Tetramers comprised of recombinant MHC molecules complexed with peptide can be used to identify populations of antigen-specific T cells. To detect T cells specific for antigens such as HER-2, gp100 and MAGE-1, fluorochrome labeled specific peptide tetramer complexes (e.g., phycoerythrin (PE)-tHLA) containing peptides from these antigens are synthesized and provided by Beckman Coulter (San Diego, CA). Specific CTL clone CD8 cells are resuspended at 10^5 cells/50 µl FACS buffer (phosphate buffer plus 1% inactivated FCS buffer). Cells are incubated with 1 µl tHLA for 30 minutes at room temperature and incubation is continued for 30 minutes at 4°C with 10 µl anti-CD8 mAb (Becton Dickinson, San Jose, CA). Cells are washed twice in 2 ml cold FACS buffer before analysis by FACS (Becton Dickinson).

ELISPOT Assay

ELISPOT assays can be used to detect cytokine secreting cells, e.g., to determine whether cells in a vaccinated patient secrete cytokine in response to antigen, thereby demonstrating whether antigen-specific responses have been elicited. ELISPOT assay kits are supplied from R & D Systems (Minneapolis, MN) and performed as described by the manufacturer's instructions. Responder (R) 1×10^5 patients' PBMC cells from before and after vaccination are plated in 96-well plates with nitrocellulose membrane inserts

coated with capture Ab. Stimulator (S) cells (TAP-deficient T2 cells pulsed with antigen) are added at the R:S ratio of 1:1. After a 24-hour incubation, cells are removed by washing the plates 4 times. The detection Ab is added to each well. The plates are incubated at 4°C overnight and the washing steps will be repeated. After a 2-hour incubation with streptavidin-AP, the plates are washed. Aliquots (100 μl) of BCIP/NBT chromogen are added to each well to develop the spots. The reaction is stopped after 60 min by washing with water. The spots are scanned and counted with computer-assisted image analysis (Cellular Technology Ltd, Cleveland, OH). When experimental values are significantly different from the mean number of spots against non-pulsed T2 cells (background values), as determined by a two-tailed Wilcoxon rank sum test, the background values are subtracted from the experimental values.

Quantitative PCR for IFN-γ production

Quantitative PCR is another means for evaluating immune responses. To examine IFN-γ production in patients by quantitative PCR, cryopreserved PBMCs from patients' pre-vaccination and post-vaccinations samples and autologous dendritic cells are thawed in RPMI DC culture medium with 10% patient serum, washed and counted. PBMC are plated at 3 x 10^6 PBMCs in 2 ml of medium in 24-well plate; dendritic cells are plated at 1x10^6/ml and are pulsed 24 hour with 10 μg/ml tumor peptide in 2 ml in each well in 24 well plate. Dendritic cells are collected, washed, and counted, and diluted to 1x 10^6 /ml, and 3x10^5 (*i.e.*, 300 μl solution) added to wells with PBMC (DC: PBMC=1:10). 2.3 μl IL-2 (300 IU/mL) is added every 3-4 days, and the cells are harvested between day 10 and day 13 after initiation of the culture. The harvested cells are then stimulated with tumor cells or autologous PBMC pulsed with 10 μg/ml tumor peptide for 4 hours at 37 °C. On days 11-13, cultures are harvested, washed twice, then divided into four different wells, two wells using for control (without target); and another two wells CTL cocultured with tumor cells (1: 1) if tumor cells are available. If tumor cells are not available, 10 μg/ml tumor lysate is added to CTL. After 4 hours of stimulation, the cells are collected, RNA extracted, and IFN-γ and CD8 mRNA expression evaluated with a thermocycler/fluorescence camera system. PCR amplification efficiency follows natural log progression, with linear regression analyses demonstrating correlation co-efficients in excess of 0.99. Based on empirical analysis, a one-cycle difference is interpreted to be a two-fold difference in mRNA quantity, and CD8-normalized IFN-γ quantities are

determined. An increase of > 1.5-fold in post-vaccine relative to pre-vaccine IFN-γ is the established standard for positive type I vaccine responsiveness.

In Vitro Induction of CTL in Patient-derived PBMCs

The following protocol can be used to produce antigen specific CTL in vitro from patient derived PBMC. To generate dendritic cells, the plastic adherent cells from PBMCs are cultured in AIM-V medium supplemented with recombinant human GM-CSF and recombinant human IL-4 at 37°C in a humidified CO_2 (5%) incubator. Six days later, the immature dendritic cells in the cultures are stimulated with recombinant human TNF-α for maturation. Mature dendritic cells are then harvested on day 8, resuspended in PBS at 1 x 10^6 per mL with peptide (2 μg/mL), and incubated for 2 hours at 37°C. Autologous CD8+ T cells are enriched from PBMCs using magnetic microbeads (Miltenyi Biotech, Auburn, CA). CD8+ T cells (2 x 10^6 per well) are cocultured with 2 x 10^5 per well peptide-pulsed dendritic cells in 2 mL/well of AIM-V medium supplemented with 5% human AB serum and 10 units/mL rhIL-7 (Cell Sciences) in each well of 24-well tissue culture plates. About 20 U/ml of IL-2 is added 24 h later at regular intervals, 2 days after each restimulation. On day 7, lymphocytes are restimulated with autologous dendritic cells pulsed with peptide in AIM-V medium supplemented with 5% human AB serum, rhIL-2, and rhIL-7 (10 units/mL each). About 20 U/ml of IL-2 is added 24 h later at regular intervals, 2 days after each restimulation. On the seventh day, after the three rounds of restimulation, cells are harvested and tested the activity of CTL. The stimulated CD8+ cultured cells (CTL) are co-cultured with T2 cells (a human TAP-deficient cell line) pulsed with 2 μg/ml Her-2, gp100, AIM-2, MAGE-1, or IL13 receptor α2 peptides. After 24 hours incubation, IFN-γ in the medium is measured by ELISA assay.

In Vivo Testing in Animal Models

Dendritic cell vaccination can be evaluated in animal models. Suitable models for brain cancers include injection models, in which cells of a tumor cell line are injected into the animal, and genetic models, in which tumors arise during development.

To evaluate dendritic cell vaccination in an animal model, functional dendritic cells are isolated from bone marrow derived cells of the animal and differentiated in vitro in the presence of cytokines, as detailed above. Mature dendritic cells are pulsed with tumor antigens (e.g., tumor antigens derived from the tumor cell line that will be

implanted into the animal, or synthetic peptides corresponding to epitopes of those antigens). Animals are implanted with cells of the tumor cell line. After implantation, animals are vaccinated with antigen-pulsed dendritic cells one or more times. Survival and immune responsiveness is measured.

Pharmaceutical Compositions

In various embodiments, the present invention provides pharmaceutical compositions including a pharmaceutically acceptable excipient along with a therapeutically effective amount of the inventive vaccine comprising dendritic cells loaded with the antigens as described herein. "Pharmaceutically acceptable excipient" means an excipient that is useful in preparing a pharmaceutical composition that is generally safe, non-toxic, and desirable, and includes excipients that are acceptable for veterinary use as well as for human pharmaceutical use. Such excipients can be solid, liquid, semisolid, or, in the case of an aerosol composition, gaseous.

In various embodiments, the pharmaceutical compositions according to the invention can be formulated for delivery via any route of administration. "Route of administration" can refer to any administration pathway known in the art, including, but not limited to, aerosol, nasal, transmucosal, transdermal or parenteral. "Parenteral" refers to a route of administration that is generally associated with injection, including intraorbital, infusion, intraarterial, intracapsular, intracardiac, intradermal, intramuscular, intraperitoneal, intrapulmonary, intraspinal, intrasternal, intrathecal, intrauterine, intravenous, subarachnoid, subcapsular, subcutaneous, transmucosal, or transtracheal. Via the parenteral route, the compositions can be in the form of solutions or suspensions for infusion or for injection, or as lyophilized powders.

The pharmaceutical compositions according to the invention can also contain any pharmaceutically acceptable carrier. "Pharmaceutically acceptable carrier" as used herein refers to a pharmaceutically acceptable material, composition, or vehicle that is involved in carrying or transporting a compound of interest from one tissue, organ, or portion of the body to another tissue, organ, or portion of the body. For example, the carrier can be a liquid or solid filler, diluent, excipient, solvent, or encapsulating material, or a combination thereof. Each component of the carrier must be "pharmaceutically acceptable" in that it must be compatible with the other ingredients of the formulation. It must also be suitable for use in contact with any tissues or organs with which it can come in contact, meaning that it must not carry a risk of toxicity, irritation, allergic response,

immunogenicity, or any other complication that excessively outweighs its therapeutic benefits.

The pharmaceutical compositions according to the invention can be delivered in a therapeutically effective amount. The precise therapeutically effective amount is that amount of the composition that will yield the most effective results in terms of efficacy of treatment in a given subject. This amount will vary depending upon a variety of factors, including but not limited to the characteristics of the therapeutic compound (including activity, pharmacokinetics, pharmacodynamics, and bioavailability), the physiological condition of the subject (including age, sex, disease type and stage, general physical condition, responsiveness to a given dosage, and type of medication), the nature of the pharmaceutically acceptable carrier or carriers in the formulation, and the route of administration. One skilled in the clinical and pharmacological arts will be able to determine a therapeutically effective amount through routine experimentation, for instance, by monitoring a subject's response to administration of a compound and adjusting the dosage accordingly. For additional guidance, see Remington: The Science and Practice of Pharmacy (Gennaro ed. 21st edition, Williams & Wilkins PA, USA) (2005). In one embodiment, a therapeutically effective amount of the vaccine can comprise about 10^7 tumor antigen-pulsed DC. In some embodiments, a therapeutically effective amount is an amount sufficient to reduce or halt tumor growth, and/or to increase survival of a patient.

Kits

The present invention is also directed to kits to treat cancers (e.g., neural cancers). The kits are useful for practicing the inventive method of treating cancer with a vaccine comprising dendritic cells loaded with the antigens as described herein. The kit is an assemblage of materials or components, including at least one of the inventive compositions. Thus, in some embodiments, the kit includes a set of peptides for preparing cells for vaccination. The kit can also include agents for preparing cells (e.g., cytokines for inducing differentiation of DC in vitro). The invention also provides kits containing a composition including a vaccine comprising dendritic cells (e.g., cryopreserved dendritic cells) loaded with the antigens as described herein.

The exact nature of the components configured in the inventive kit depends on its intended purpose. For example, some embodiments are configured for the purpose of treating neural cancers. Other embodiments are configured for the purpose of treating

brain tumors. In one embodiment the brain tumor is a glioma. In another embodiment, the brain tumor is GBM. In another embodiment, the brain tumor is an astrocytoma. In one embodiment, the kit is configured particularly for the purpose of treating mammalian subjects. In another embodiment, the kit is configured particularly for the purpose of treating human subjects. In further embodiments, the kit is configured for veterinary applications, treating subjects such as, but not limited to, farm animals, domestic animals, and laboratory animals.

Instructions for use can be included in the kit. "Instructions for use" typically include a tangible expression describing the technique to be employed in using the components of the kit to effect a desired outcome, such as to treat cancer. For example, the instructions can comprise instructions to administer a vaccine comprising dendritic cells loaded with the antigens described herein to the patient. Instructions for use can also comprise instructions for repeated administrations of the vaccine; for example, administering the three doses of the vaccine in two week intervals.

Optionally, the kit also contains other useful components, such as, diluents, buffers, pharmaceutically acceptable carriers, syringes, catheters, applicators, pipetting or measuring tools, or other useful paraphernalia as will be readily recognized by those of skill in the art.

The materials or components assembled in the kit can be provided to the practitioner stored in any convenient and suitable ways that preserve their operability and utility. For example the components can be in dissolved, dehydrated, or lyophilized form; they can be provided at room, refrigerated or frozen temperatures. The components are typically contained in suitable packaging material(s). As employed herein, the phrase "packaging material" refers to one or more physical structures used to house the contents of the kit, such as inventive compositions and the like. The packaging material is constructed by well known methods, preferably to provide a sterile, contaminant-free environment. The packaging materials employed in the kit are those customarily utilized in cancer treatments or in vaccinations. As used herein, the term "package" refers to a suitable solid matrix or material such as glass, plastic, paper, foil, and the like, capable of holding the individual kit components. Thus, for example, a package can be a glass vial used to contain suitable quantities of an inventive composition containing for example, a vaccine comprising dendritic cells loaded with the antigens as described herein. The packaging material generally has an external label which indicates the contents and/or purpose of the kit and/or its components.

EXAMPLES

The following examples are provided to better illustrate the claimed invention and are not to be interpreted as limiting the scope of the invention. To the extent that specific materials are mentioned, it is merely for purposes of illustration and is not intended to limit the invention. One skilled in the art can develop equivalent means or reactants without the exercise of inventive capacity and without departing from the scope of the invention.

Example 1. Human Studies

Phase I studies were initiated in two human patients to assess the safety and efficacy of an immunotherapy trial using peripheral blood dendritic cells to present brain tumor-specific markers to the patient's immune system. The details of these studies are described in Examples 2-8 below.

No significant adverse events (grade III/IV toxicity) have been noted in the patients thus far.

Example 2. Preparation of Autologous Dendritic Cells (DC)

Mononuclear cells were isolated from patients between days -28 to -14 using leukapheresis. The COBE Spectra Apheresis System was used to harvest the mononuclear cell layer. Leukapheresis yields 10^{10} peripheral blood mononuclear cells (PBMC). These cells were allowed to become adherent for two hours at 37°C in a tissue culture flask and washed in HBSS. Briefly, PBMC were seeded at a density of 1.4 x 10^6 cells/cm^2 in 185-cm^2 culture flasks (Nunc, Roskilde, Denmark) and allowed to adhere for 2 h at 37°C. Non-adherent cells were removed by washing four times. Adherent cells were cultured in RPMI 1640 supplemented with GM-CSF (Berlex) and IL-4 (R&D systems) for 5 days. On day 5, 50 ng/ml clinical grade TNF-α (R&D systems) was added to the culture medium for another 3-4 days. On days 8-9, DCs were harvested and washed three times.

Patients underwent the following tests within 7 days of Leukapheresis procedure: ABO/Rh; Antibody Screen; Syphilis; HBsAg; HBcAb; anti-HCV; anti-HIV1, 2; anti-HTLV I/II; and HIV-1/HCV by Nucleic Acid Testing (NAT) (ABO/Rh does not need to be repeated within 7 days of Leukapheresis). Table 3 lists the names, manufacturers, methods, and an explanation of each of these tests.

Table 3

TEST NAME ABBREV.	REAGENT MANUFACTURER	TEST METHOD	BRIEF EXPLANATION
Blood Group ABO/Rh	Gamma Biologicals, Inc. & Ortho Diagnostic Systems, Inc. a Johnson & Johnson Company	Olympus PK System PK7200 an Automated Pretransfusion Testing System & Manual Tube Test	Testing is necessary to determine if red blood cells possess or lack A and/or B and D blood group antigens. Agglutination is a positive test result indicating the presence of the corresponding antigen. Normal human red blood cells possessing antigens will agglutinate in the presence of antibody directed toward the antigens.
Blood Group ABO/Rh (Alternate)	Micro Typing Systems, Inc.	A/B/D Monoclonal Grouping Card A/B/D Reverse Monoclonal Grouping Card MTS Anti-IgG Card	
Antibody Screen Ab	Immucor, Inc. Norcross,GA	Capture-R Ready Screen	A qualitative test for the detection of unexpected blood group antibodies. Used to detect unexpected antibodies in the serum or plasma from donors.
Antibody Screen Ab (Alternate)	Micro Typing Systems, Inc.	MTS Anti-IgG Card	
Hepatitis B Surface Antigen HBsAg	Ortho-Clinical Diagnostics, Inc. Raritan, NJ	Antibody to Hepatitis B Surface Antigen (Murine Monoclonal): Peroxidase Conjugate ORTHO Antibody to HbsAg ELISA Test System 3	This enzyme immunoassay (EIA) detects the presence of hepatitis B surface antigen (HbsAg) in human serum or plasma.
Human Immunodeficiency Virus Types 1 and 2 HIV-1/2	Bio-Rad Laboratories, Redmond, WA	Human Immunodeficiency Virus Types 1 and 2 (Synthetic Peptide): Genetic Systems HIV-1/HIV-2 Peptide EIA	This enzyme-linked immunoassay (EIA) allows simultaneous detection of antibodies to HIV-1 and HIV-2. It does not discriminate between HIV-1 and HIV-2 reactivity.
Syphilis Serology SYP	Olympus America Inc., Melville, NY	Olympus PK TP System	This test is intended for the qualitative detection of Treponema pallidum antibodies in human serum or plasma. This agglutination test utilizes fixed chicken erythrocytes sensitized with components of the pathogenic T. pallidum to detect antibodies in specimens.
Syphilis Serology (Alternate)	Immucor, Inc., Norcross, GA	Capture-S	

Human T-Lymphotrophic Virus Type I and Type II HTLV-I/II	BIOMERIEUX, Inc., Durham, NC	Human T-Lymphotrophic Virus Type I and Type II (HTLV-I/II): Vironostika HTLV-I/II Microelisa System	This enzyme-linked immunoassay (EIA) detects antibodies to HTLV-I and antibodies to HTLV-II.
Hepatitis C Virus Encoded Antigen HCV	ORTHO Clinical Diagnostics, Inc., Raritan, NJ	Hepatitis C Virus Encoded Antigen (Recombinant c22-3, C200 and NS5) ORTHO HCV Version 3.0 ELISA Test System	This enzyme immunoassay utilizes recombinant antigens to detect antibody to Hepatitis C virus (HCV). Presence of this antibody indicates past or present HCV infection, or possibly a carrier state, but does not substantiate infectivity nor immunity. The anti-HCV EIA 3.0 version test includes NS5, c200, and c22-3 recombinant antigens. The NS antigen is derived from the polymerase of the HCV genome and allows antibody detection of a greater number of HCV epitopes.
Nucleic Acid Testing (NAT) Procleix HIV-1/HCV RNA NAT	Gen-Probe Incorporation, San Diego, CA	Procleix HIV-1/HCV Assay	This assay utilizes target amplification nucleic acid probe technology for the detection of HIV-1 and/or HCV RNA. The screen assay is referred to as "multiplex testing" which does not discriminate between HIV-1 and HCV RNA. Specimens found to be reactive upon multiplex testing are then tested in HIV-1 and HCV Discriminatory Assays (dHIV and dHCV assays) to determine if they are reactive for HIV, HCV, both or neither. All assays have a chemiluminescent signal produced by a hybridized probe, which is measured by a luminometer and reported as Relative Light Units (RLU).

Example 3. Preparation of Vaccines

Human leukocyte antigen A1 (HLA-A1, or A1) and human leukocyte antigen A2 (HLA-A2, or A2) positive patients with recurrent brain stem glioma or glioblastoma were identified. Dendritic cells, prepared as described in Example 2, were pulsed with peptide epitopes of tumor antigens that bind to HLA-A1 or HLA-A2, to load the cells with the antigens, prior to frozen storage. The peptide epitopes were from the following tumor antigens: MAGE-1, HER-2, AIM-2, TRP-2, gp100, and interleukin-13 receptor α2. The sequences of these peptide epitopes used in these studies are listed in Table 4, below. Other epitopes for these antigens can also be used.

Table 4. Tumor Antigen Peptides

Antigen	HLA-A1 epitope	Antigen	HLA-A2 epitope
AIM-2	RSDSGQQARY (SEQ ID NO:3)	TRP-2	SVYDFFVWL (SEQ ID NO:5)
MAGE-1	EADPTGHSY (SEQ ID NO:4)	GP100	ITDQVPFSV (SEQ ID NO:6)
		HER-2	KIFGSLAFL (SEQ ID NO:7)
		IL-13R α2	WLPFGFILI (SEQ ID NO:8)

Tumor antigen epitopes were purchased from Clinalfa (Läufelfingen, Switzerland).

On the day prior to immunization, days 8-9 DC cultures were washed three times in dPBS, resuspended at 10^6 cells/ml in complete media and then coincubated with tumor associated antigen peptides (10 μg/ml per antigen, reconstituted in 10% DMSO). The dendritic cells were incubated with the peptides at 37°/5% CO_2 for 16-20 hours on a tissue rotator to facilitate interaction.

Mature (d8-9) DC were frozen as follows: DC are resuspended in cryo tubes at various concentrations (1×10^7 cells per ml in autologous freezing medium (10% DMSO and 90% autologous serum), then immediately transferred to 1.8 ml cryo tubes (cryo tube vials, Nunc, Brand Products, Roskilde, Denmark), slowly frozen to −80°C by using a cryo freezing container (Nalgene cryo 1°C freezing container, rate of cooling −1°C/min (Fisher Scientific, CA)) and finally transferred into the gas phase of liquid nitrogen until use.

Sterility testing was conducted to confirm suitability for use. To test sterility, APC were cultured in RPMI medium, 10% heat-inactivated human AB serum, and 1% Gentamicin "GIBCO". Purchased Human AB serum was heat inactivated to 56°C for one hour prior to preparation of complete medium. Each batch of complete medium was prepared on the day of each blood draw and sterile filtered (.22 μm filter; Nalgene) prior to use. Complete media was refrigerated during the 9 day APC culture period. On day 2 of the APC culture, an aliquot of spent culture media was removed and subjected to sterility testing using BacT/Alert system with aerobic and anaerobic bottles that are cultured for 14 days total in an automated system.

In addition, a gram stain, sterile culture, mycoplasma, and LAL endotoxin assays are performed on the final product before the administration to the patient.

Acceptance Criteria for Test Article: 5 Eu/ml/kg of patient (endotoxin); no growth in sterility cultures; no bacteria seen by gram staining, hybridization control positive, water control negative, and the vaccine product exhibiting no sustained logarithmic increase in fluorescence intensity for mycoplasma QPCR.

Example 4. Protocol for Administering the Vaccine

For immunization, the patient received 10^7 tumor antigen-pulsed dendritic cells, intradermally in 1 ml autologous freezing media in the axillary region. The patient was monitored for two hours post-immunization. Patients can receive pretreatment with 50 mg diphenhydramine and 650 mg of Tylenol, both orally (only as needed to treat symptoms or for the prevention of the recurrence of any prior study-agent-associated symptoms). The schedule of vaccine administration, and pre- and post- vaccine testing is shown in Table 5. The schedule of blood draws for vaccine preparation and testing is shown in Table 6.

Table 5. Vaccination and Immunological Testing Schedule

Day	Events
-28 to -14	A patient is screened and informed consent is obtained. MRI, Blood draw for serum (to supplement freezing medium), Immunological tests (pretreatment), Leukapheresis and preparation of dendritic cells is performed.
0	TAA-pulsed APC vaccination (1st).
14	TAA -pulsed APC vaccination (#2).
28	TAA-pulsed APC vaccination (#3).
56	Immunological tests, MRI, AE assessment, blood tests, targeted exam, Karnofsky (week 10), MRI every 2 months, are performed.
180	Immunological tests are performed (month 4).

Table 6. Specific Blood Draw and Volume Schedule

Day	Event	Vol.
-28	Blood draw for serum+ DC's	100 ml
-28	Immunological tests	70 ml
56	Immunological tests	70 ml
180	Immunological tests	70 ml

Example 5. Screening and Baseline Evaluations

The following clinical and laboratory evaluations occur within days -28 to -9 unless otherwise noted.

- Objective Signs and Symptoms: Includes vital signs (blood pressure, pulse, temperature and respirations), and weight. (Screening and repeat Day 0.)
- History and Review of Systems: Screening and Review of Systems on Day -28 to -9, repeated Neurological exam on Day 0.
- Karnofsky Performance Status (Screening)

KARNOFSKY INDEX:

100	Normal; no complaints; no evidence of disease.
90	Able to carry on normal activity; minor signs or symptoms.
80	Normal activity with effort; some signs or symptoms.
70	Cares for self; unable to carry on normal activity or to do active work.
60	Requires occasional assistance; able to care for most needs.
50	Requires considerable assistance; able to care for most needs.
40	Disabled; requires special care and assistance.
30	Severely disabled; hospitalization necessary; active supportive treatment necessary.
20	Very sick; hospitalization necessary; active supportive treatment necessary.
10	Moribund; rapidly progressing fatal process.
0	Dead.

- MRI of Brain with and without contrast

- Urinalysis: Normal routine urinalysis
- Serum Chemistries: Includes uric acid, calcium, phosphorous, magnesium, amylase, triglycerides, transaminases (AST, ALT), alkaline phosphatase, LDH, total bilirubin, BUN, creatinine, albumin, total protein, electrolytes, glucose (Screening), ANA, and TSH.
- Hematology: Complete blood count (CBC), differential, platelets, and coagulation tests should include PT (Prothrombin Time) and PTT (Partial Thromboplastin Time). PT and PTT will be done at screening only and are repeated if clinically indicated.

Example 6. Interval Evaluations

Objective Signs and Symptoms: vital signs (blood pressure, pulse, temperature and respiration) and weight will be done.

Review of Systems: Neurological exam will be done on Study Days (i.e., days when the patient sees a physician).

Karnofsky Performance Status are done on Study Days.

Serum Chemistries: Include uric acid, calcium phosphorous, magnesium, amylase, triglycerides, transaminases (AST, ALT), alkaline phosphatase, LDH, total bilirubin, BUN, creatinine, albumin, total protein, electrolytes glucose, ANA, and TSH.

Hematology: Complete blood count (CBC), differential platelets and coagulation tests should include PT (Prothrombin time) and PTT (Partial Thromboplastin time).

MRI of brain with and without contrast (q2 months).

Example 7. Vaccination Modification and General Management of Toxicities

A Table for Grading Severity of Adverse Experience (AE) is used to achieve consistency in response to drug/treatment toxicities. Toxicities are graded on the NIH Common Toxicity Criteria , a 1-4 basis scale. If a toxicity is experienced, the treatment level or dose is modified (if applicable) as outlined below according to the grade of toxicity observed. AEs related to neurological deficits or post-vaccination therapy due to tumor progression. All SAEs will be reported until survival.

For any Grade 1 toxicity there will be no dose modification.

If a Grade 2 toxicity develops, the patient will not receive a planned subsequent vaccine injection until values return to Grade 1 or less for at least one week.

All vaccine administrations will cease for any patient who experiences any of the following outcomes within one month following any vaccine injection: any grade 3 or 4 adverse event; a grade 2 (or greater) allergic adverse event; or a grade 2 (or greater) neurologic adverse event not readily attributable to the tumor.

Symptomatic therapy such as analgesics or other helpful therapy can be administered if deemed necessary.

Example 8. Primary Safety and Efficacy Analyses

The primary safety outcome is number of Grade 3 or 4 toxicities. Safety outcomes are followed over a period of one year following the last study agent dose administration.

The primary endpoint is survival time (from date of vaccination to date of death or the last date known alive if death was not observed).

The secondary endpoints of progression free survival after vaccination are measured radiologically with MRI scan of the brain with and without gadolinium. Patients will undergo an MRI every two months after the last study agent administration Standardized response criteria as outlined below have been adopted.

Complete Response: Complete disappearance of all tumor on MRI with a stable or improving neurologic examination.

Partial Response: Greater than or equal to 50% reduction in tumor size on volumetric MRI scan with a stable or improving neurologic examination.

Progressive Disease or Recurrent Disease: Progressive neurologic abnormalities or a new or greater than 25% increase in the volume of the gadolinium-enhancing tumor by MRI scan.

Stable Disease: A patient whose clinical status and MRI volumetrics do not meet the criteria for partial response or progressive disease.

Dose limiting toxicities are followed for one month after the last study agent administration.

Example 9. In Vivo Testing in an Animal Model

The following in vivo animal experiments demonstrate the efficacy of a dendritic cell vaccine. To isolate functional dendritic cells (DC), cells were harvested from rat bone marrow. Bone marrow suspensions were supplemented with GM-CSF (50 ng/ml)

and IL-4 (100 ng/ml) for 8 days, which have been shown to induce the differentiation of functional dendritic cells. Mature dendritic cells from culture were positively identified based on their surface antigen expression via flow cytometry (FACS). Dendritic cells were positively identified based on their expression of MHC Class II, MHC Class I, CD11b/c, and Thy1.1, and their lack of CD3 and CD8 expression. Cultures enriched for dendritic cells were pulsed (co-cultured) overnight with acid eluted tumor peptides from syngeneic 9L rat glioma cells.

In these animal experiments, 9L glioma cells were stereotactically implanted into the right cerebral hemisphere of Fischer 344 rats. One week after tumor implantation, animals were injected subcutaneously with $5x10^5$ 9L peptide-pulsed dendritic cells, unpulsed dendritic cells or control media. Three weekly injections were given. Animals in each of the treatment groups were followed for survival. The results revealed that a significantly higher percentage of animals treated with 9L peptide-pulsed dendritic cells were still surviving at 20 days (10/12 = 83%) compared to those treated with unpulsed cells (2/6 = 33%) or untreated animals (3/10 = 30%).

Example 10. Enhanced Immune Responsiveness to T cell Epitopes with Dibasic Motifs

In studies using mouse lysozyme-M (ML-M) as a model self Ag, it was observed that mice of diverse MHC haplotypes were tolerant to native (unmutated) ML-M and peptide forms of certain T cell epitopes. It was hypothesized that tolerance to a given epitope was not an inherent structural characteristic, but was attributable in part to inefficient processing of the epitope, owing either to the absence of a proteolytic cleavage site adjacent to that determinant, or to the inaccessibility to the proteolytic enzyme(s) of an existing cleavage site within that region of the molecule. In either case, the provision of a new proteolytic cleavage site adjacent to a cryptic determinant may permit scission of the peptide at that site, making the previously cryptic epitope region available for binding to the appropriate MHC molecule, and lead to presentation to specific T cells of that determinant as a neodominant epitope on the APC surface. To test this proposition, a dibasic motif, consisting of two contiguous basic amino acid residues, e.g., arg-arg (RR) or arg-lys (RK), was used.

The targeted regions within ML-M included residues 19-31, which contain cryptic epitopes for mice of the H-2^k haplotype, shown in Table 7.

Table 7. Creation of Dibasic Motifs in Flanking Region of a Defined Cryptic Epitope Within ML-M

Target ML-M Epitope[a] / Dominant Epitope for Mouse Strain (H-2)[a]	ML-M T cell epitope	Dibasic Site	Resulting Dibasic Motif
19-30 C3H/HeJ (H-2^k)	RR-GYYGVSLADWVC (SEQ ID NO:60)	18	RR
19-30 C3H/HeJ (H-2^k)	GYYGVSLADWVC-RR (SEQ ID NO:61)	31	RR
19-30 C3H/HeJ (H-2^k)	RR-GYYGVSLADWVC-RR (SEQ ID NO:62)	18+31	RR-RR

Groups of mice (3 per group) were immunized by IV injection of each peptide (ML-M, p19-30, or 18R31R. T cells were isolated from lymph node of the animals. Single cells in 96 well plates were recalled with each of the peptides and response to each of the peptides was measured. Interestingly, C3H mice challenged with ML-M failed to respond to the immunogen and to various peptides of this self lysozyme, including peptide 19–31, whereas immunization with RR-p18-31-RR raised a potent T cell response to this altered lysozyme as well as to p19–30 (FIG. 1). These results demonstrate that the dibasic site RR/KK mediated an efficient processing of the epitope 19–30, leading to activation of specific T cells. Furthermore, the T cells primed by RR-p18-31-RR could be restimulated in vitro with RR-p18-31-RR, but not by ML-M or peptides from other regions of ML-M. These results further confirmed the efficient presentation by the APC of epitope 19–30, but not ML-M to specific T cells, and also demonstrated the T cell cross-reactivity with synthetic p19–30.

Studies related to these studies with ML-M are performed with HER-2. HER-2/neu is a self-antigen expressed by tumors and nonmalignant epithelial tissues. The possibility of self-tolerance to HER-2/neu-derived epitopes has raised questions concerning their utility in antitumor immunotherapy. Altered HER-2/neu peptide ligands capable of eliciting enhanced immunity to tumor-associated HER-2/neu epitopes may circumvent this problem. The human CTL peptide HER-2/neu (435-443) modified with RR or RK dibasic motifs is an example of an altered peptide ligand of HER2.

The following exemplary dibasic-modified forms of HER2 peptides are obtained from Macromolecular Resources and Global Peptide Services: hHER-2(9_{435}) (RRILHNGAYSLRR)(SEQ ID NO:1) and RRKIFGSLAFLRR (SEQ ID NO:2).

Murine in vivo Lymphocyte proliferation assay

To test immunogenicity in an animal model, mice are immunized s.c. either altered hHER-2 peptide or with a peptide of hHER-2 (1 mg/ml each), each emulsified in complete Freunds adjuvant (CFA; Invitrogen Life Technologies) (1:1, v/v). After 8 or 9 days, the draining lymph node cells (5 x 10^5/well) of these mice are tested in a proliferation assays using the appropriate peptides. Purified protein derivative (PPD) (Mycos Research) is used as a positive control. The incorporation of radioactivity ([^{3}H]thymidine) is assayed by liquid scintillation counting. The results will be expressed either as counts per minute (cpm) or as a stimulation index (stimulation index = cpm with recall antigen/cpm with cells in medium alone).

In vitro cell proliferation assay using paraformaldehyde (PF)-fixed APC

Cell proliferation is tested in vitro using the following assay. Briefly, DC from PBMC are used as APC. APC are fixed by incubation with 0.5% paraformaldehyde (PF; Sigma-Aldrich) for 10 min at room temperature either before or after pulsing with antigen. Naive unfixed APC are used as a control for fixed APC. Antigen-primed T cells are purified from LNC and spleen of antigen-challenged mice using a nylon wool column (Polysciences), and then cultured (1.5 x 10^5/well) with fixed/unfixed APC (3.75 x 10^5/well). APC plus T cells without Ag, and T cells with Ag only (no APC) serve as additional controls. The results are expressed as cpm or stimulation index, as described above.

T cell ATP release function assay

DC are pulsed with peptides for 16-20 hours, then incubated with CD4/CD8 T cells overnight and analyzed with an ATP releasing T cell proliferation assay. Table 8 lists the correlation of ATP levels with immune responsiveness, and suitability for a vaccine.

Table 8. Correlation of ATP Level with Immune Response

ATP Range (ng/mL)	Immune Response	Interpretation Vaccine
225	Low	-
226-524	moderate	+/-
525	strong	+

Measurement of the cytokine levels

LNC of antigen-primed mice are restimulated with antigen in vitro for 48 h. Thereafter, the culture supernatants are collected and assayed by ELISA using kits for IFN-γ and IL-4 (BioSource International). The absorbance is read at 450 nm using MicroElisa autoreader (Molecular Devices). The results are expressed as Δpg/ml (= cytokine secreted by LNC with Ag – cytokine in medium control). The Th1/Th2 ratio is derived from the levels of IFN-γ/IL-4, respectively.

Determination of the serum levels of Ag-specific Abs

The level of antibodies (total IgG, IgG1, and IgG2a) in sera is tested at different dilutions and detected by ELISA using different antigen (0.1 μg/well of a high binding ELISA plate (Greiner Bioscience)) and the appropriate HRP-conjugated secondary Ab against total Ig, or Ab specific for the IgG1 or IgG2a isotype (BD Pharmingen) (1:1000) following standard procedures. The results will be expressed as OD (450 nm) units.

Example 11. IFN-γ production of Altered Peptide ligands (APL)-specific CTLs

The immunogenicity of the APLs (also referred to herein as superagonist epitopes) in two HLA-A*0201 GBM patients were tested to determine the capacity of prime CTL responses *in vitro*. The results of these experiments are depicted in Figures 2 and 3.

For the gp100 APLs, among six different CTLs stimulated by six different peptides, No. 38 showed the highest IFN-γ level when targeting T2 pulsed with gp100 native peptide in both patients. There was a significant difference ($P<0.05$) when CTL No. 38 was compared with CTL generated by the gp100 (2M) peptide.

For the Her-2 APLs, among four different CTLs stimulated by four different peptides, No. 19 showed the highest IFN-γ level when targeting T2 pulsed Her-2 native peptide in both patients. There was a significant difference ($P<0.05$) when CTL No. 19 was compared with CTL generated by CTL No.52 and CTL generated by Her-2 native peptide. In conclusion, among the tested peptides, No. 38 and No. 19 are the best superagonists.

Tables 9 and 10 list the altered peptide ligand (*i.e.*, superagonist epitope) sequences of gp-100 and Her-2, respectively. The bolded letters indicate the amino acid that is substituted in place of the native amino acid residue. gp100 (2M) is an analog of

the native gp100 with a replacement of the amino acid T with M. The native gp100 peptide sequence is as follows: ITDQVPFSV (SEQ ID NO:6). Peptide No. 52 is a native HER-2 peptide and not an altered peptide. The peptides were dissolved in 5% DMSO at 2 mg/ml and stored at -20°C until taken out for use.

Table 9

Amino acid sequences of gp100 APL												
gp100 (2M)	H-	I	T	D	Q	V	P	F	S	V	-NH_2	SEQ ID NO:6
No. 8	H-	**F**	**L**	D	Q	V	P	**Y**	S	V	-NH_2	SEQ ID NO:63
No. 22	H-	**F**	**M**	D	Q	V	P	**Y**	S	V	-NH_2	SEQ ID NO:64
No. 38	H-	**Y**	**M**	D	Q	V	P	**Y**	S	V	-NH_2	SEQ ID NO:65
No. 62	H-	I	**L**	D	Q	V	P	F	S	V	-NH_2	SEQ ID NO:66
No. 63	H-	I	**M**	D	Q	V	P	F	S	V	-NH_2	SEQ ID NO:67

Table 10

Amino acid sequences of HER-2 APL														
No. 19	H-	**F**	M	A	**N**	V	**A**	**I**	P	**H**	**L**	-NH_2	SEQ ID NO:68	cp1
No. 32	H-	**F**	M	**H**	**N**	V	**P**	**I**	P	Y	**L**	-NH_2	SEQ ID NO:69	cp14
No. 41	H-	**F**	**Y**	A	**N**	V	**P**	S	P	**H**	**L**	-NH_2	SEQ ID NO:70	cp23
No. 52	H-	V	M	A	G	V	G	S	P	Y	V	-NH_2	SEQ ID NO:71	native, C-terminal amide

Example 12. In vitro induction of CTL in patient-derived PBMCs and Stimulation with Altered Peptide Ligands (Superagonist Peptides)

The following assays were used to further evaluate immune responses to the altered peptide ligands described in Example 11. To generate dendritic cells, plastic-adherent cells from human PBMCs were cultured in AIM-V medium supplemented with recombinant human GM-CSF and recombinant human IL-4 at 37°C in a humidified CO_2 (5%) incubator. Six days later, the immature dendritic cells were stimulated with recombinant human TNF-α for maturation. Mature dendritic cells were then harvested on day 8, resuspended in PBS at 1 x 10^6 per mL with peptide (2 μg/mL), and incubated for 2 hours at 37°C.

Autologous CD8+ T cells were enriched from PBMCs using magnetic microbeads (Miltenyi Biotech, Auburn, CA). CD8+ T cells (2 x 10^6 per well) were cocultured with 2

x 10^5 per well peptide-pulsed dendritic cells in 2 mL/well of AIM-V medium supplemented with 5% human AB serum and 10 units/mL rhIL-7 (Cell Sciences) in each well of 24-well tissue culture plates. The gp100 and Her-2 peptides used for pulsing the dendritic cells are described in Example 11. On the next day and then every 3 days, 300 IU/ml IL-2 was added to the medium. On day 7, lymphocytes were restimulated with autologous dendritic cells pulsed with peptide in AIM-V medium supplemented with 5% human AB serum, rhIL-2, and rhIL-7 (10 units/mL each).

CTL co-culture with GBM tumor cells

After three cycles of stimulation, on day 20, the CD8+ cultured cells (CTL) were co-cultured with four GBM cell lines, which are both HLA-A2 and HER-2, gp100 positive cell lines. After a 24 hour incubation, IFN-γ in the medium was measured by ELISA assay. The data are shown in FIG.4 and FIG. 6.

ELISPOT Assays

ELISPOT assays were performed with kits (R & D Systems, Minneapolis, MN) according to the manufacturer's instructions. After three cycles of stimulation, on day 20, the CD8+ cultured cells (CTL) were plated in 96-well plates with nitrocellulose membrane inserts coated with capture antibody (Ab). Target cells (T2 pulsed HER-2 native peptide for FIG. 5 or T2 pulsed gp100 native peptide for FIG. 7) were added at the CTL: target ratio of 1:1. After a 24 hour incubation, cells were removed by washing the plates 4 times. The detection Ab was added to each well. The plates were incubated at 4°C overnight and the washing steps were repeated. After a 2 hour incubation with streptavidin-AP, the plates were washed. Aliquots (100 μl) of BCIP/NBT chromogen were added to each well to develop the spots. The reaction was stopped after 60 minutes by washing with water. The spots were scanned and counted with computer-assisted image analysis (Cellular Technology Ltd, Cleveland, OH). When experimental values were significantly different from the mean number of spots against non-pulsed T2 cells (background values), as determined by a two-tailed Wilcoxon rank sum test, the background values were subtracted from the experimental values. The coefficient of variation of intra-assay for ELISPOT in these experiments was less than 10%. The data are shown in FIG. 5 and FIG. 7.

OTHER EMBODIMENTS

It is to be understood that while the invention has been described in conjunction with the detailed description thereof, the foregoing description is intended to illustrate and not limit the scope of the invention, which is defined by the scope of the appended claims. Other aspects, advantages, and modifications are within the scope of the following claims.

WHAT IS CLAIMED IS:

1. A method for treating a cancer in a patient, the method comprising:

administering to the patient a composition comprising dendritic cells, wherein the dendritic cells present on their surface peptide epitopes comprising amino acid sequences corresponding to epitopes of at least four of the following six antigens: tyrosinase-related protein (TRP)-2, Melanoma-associated Antigen-1 (MAGE-1), HER-2, interleukin-13 receptor α2 (IL-13 receptor α2), gp100, and Antigen isolated from Immunoselected Melanoma-2 (AIM-2), wherein at least one of the peptide epitopes is a superagonist peptide epitope.

2. The method of claim 1, wherein the dendritic cells acquired the peptide epitopes in vitro by exposure to synthetic peptides comprising the peptide epitopes.

3. The method of claim 2, wherein the synthetic peptides comprise a synthetic peptide having a dibasic motif at the N-terminus and a dibasic motif at the C-terminus.

4. The method of claim 1, wherein the cancer is a glioma.

5. The method of claim 2, wherein the synthetic peptides comprise 9-13 amino acid residues.

6. The method of claim 1, wherein the dendritic cells comprise peptide epitopes corresponding to TRP-2, MAGE-1, HER-2, IL-13 receptor α2, gp100, and AIM-2.

7. The method of claim 1, wherein the composition is administered to the patient two or more times.

8. The method of claim 1, wherein the composition comprises between 10^5 to 10^7 dendritic cells.

9. The method of claim 1, wherein the peptide epitopes comprise at least one peptide with one of the following sequences:

RSDSGQQARY (SEQ ID NO:3) from AIM-2;
EADPTGHSY (SEQ ID NO:4) from MAGE-1;
SVYDFFVWL (SEQ ID NO:5) from TRP-2;
ITDQVPFSV (SEQ ID NO:6) from gp100;
KIFGSLAFL (SEQ ID NO:7) from HER-2; and
WLPFGFILI (SEQ ID NO:8) from IL-13 receptor α2.

10. The method of claim 1, wherein the peptide epitopes comprise one or both of the following superagonist peptide sequences:
YMDQVPYSV (SEQ ID NO:65) from gp100;or
FMANVAIPHL (SEQ ID NO:68) from HER-2.

11. The method of claim 1, wherein the peptide epitopes comprise one of the following superagonist peptide sequences:
FLDQVPYSV (SEQ ID NO:63) from gp100
ILDQVPFSV (SEQ ID NO:66) from gp100; or
IMDQVPFSV (SEQ ID NO:67) from gp100.

12. The method of claim 1, wherein the peptide epitopes comprise one of the following superagonist peptide sequences:
FMHNVPIPYL (SEQ ID NO:69) from HER-2; or
FYANVPSPHL (SEQ ID NO:70) from HER-2.

13. The method of claim 1, wherein the composition comprises autologous dendritic cells.

14. The method of claim 4, wherein the glioma is glioblastoma multiforme.

15. The method of claim 4, wherein the glioma is an astrocytoma.

16. A method for preparing a cell vaccine for treating a glioma, the method comprising:
obtaining bone marrow derived mononuclear cells from a patient,
culturing the mononuclear cells in vitro under conditions in which mononuclear cells become adherent to a culture vessel,
selecting a subset of the mononuclear cells comprising adherent cells,

culturing the adherent cells in the presence of one or more cytokines under conditions in which the cells differentiate into antigen presenting cells,

culturing the antigen presenting cells in the presence of synthetic peptides, the peptides comprising amino acid sequences corresponding to epitopes of at least four of the following six antigens: TRP-2, MAGE-1, HER-2, IL-13 receptor α2, gp100, and AIM2, wherein at least one of the peptide epitopes is a superagonist peptide epitope, under conditions in which the cells present the peptides on major histocompatibility class I molecules, thereby preparing a cell vaccine.

17. The method of claim 14, wherein the synthetic peptides comprise epitopes corresponding to TRP-2, MAGE-1, HER-2, IL-13 receptor α2, gp100, and AIM-2.

18. The method of claim 16, wherein the synthetic peptides comprise a synthetic peptide having a dibasic motif at the N-terminus and a dibasic motif at the C-terminus.

19. The method of claims 16, wherein the one or more cytokines comprise granulocyte macrophage colony stimulating factor and interleukin-4 (IL-4).

20. The method of claim 16, wherein the one or more cytokines comprise tumor necrosis factor-α (TNF-α).

21. The method of claim 16, wherein the bone marrow derived cells are obtained from a patient with a glioma, and wherein the cell vaccine is prepared to treat the patient.

22. The method of claim 16, wherein the synthetic peptides comprise at least one peptide comprising one of the following sequences:

RSDSGQQARY (SEQ ID NO:3) from AIM-2;
EADPTGHSY (SEQ ID NO:4) from MAGE-1;
SVYDFFVWL (SEQ ID NO:5) from TRP-2;
ITDQVPFSV (SEQ ID NO:6) from gp100;
KIFGSLAFL (SEQ ID NO:7) from HER-2; and
WLPFGFILI (SEQ ID NO:8) from IL-13 receptor α2.

23. The method of claim 22, wherein the synthetic peptides comprise one or both of the following superagonist peptide sequences:

YMDQVPYSV (SEQ ID NO:65) from gp100; or

FMANVAIPHL (SEQ ID NO:68) from HER-2.

24. The method of claim 22, wherein the peptide epitopes comprise one of the following superagonist peptide sequences:

FLDQVPYSV (SEQ ID NO:63) from gp100;

ILDQVPFSV (SEQ ID NO:66) from gp100; or

IMDQVPFSV (SEQ ID NO:67) from gp100.

25. The method of claim 22, wherein the peptide epitopes comprise one of the following superagonist peptide sequences:

FMHNVPIPYL (SEQ ID NO:69) from HER-2; or

FYANVPSPHL (SEQ ID NO:70) from HER-2.

26. A kit for preparing a cell vaccine for treating a cancer, the kit comprising:

a set of synthetic peptides, the peptides comprising amino acid sequences corresponding to epitopes of at least four of the following six antigens: TRP-2, MAGE-1, HER-2, IL-13 receptor α2, gp100, and AIM2, wherein at least one of the peptides is a superagonist peptide.

27. The kit of claim 26, wherein the synthetic peptides comprise a synthetic peptide having a dibasic motif at the N-terminus and a dibasic motif at the C-terminus.

28. The kit of claim 26, wherein the synthetic peptides comprise at least one of the following sequences:

RSDSGQQARY (SEQ ID NO:3) from AIM-2;

EADPTGHSY (SEQ ID NO:4) from MAGE-1;

SVYDFFVWL (SEQ ID NO:5) from TRP-2;

ITDQVPFSV (SEQ ID NO:6) from gp100;

KIFGSLAFL (SEQ ID NO:7) from HER-2; and

WLPFGFILI (SEQ ID NO:8) from IL-13 receptor α2.

29. The kit of claim 26, wherein the synthetic peptides comprise one or both of the following superagonist peptide sequences:

YMDQVPYSV (SEQ ID NO:65) from gp100; or

FMANVAIPHL (SEQ ID NO:68) from HER-2.

30. The kit of claim 26, wherein the synthetic peptides comprise one of the following superagonist peptide sequences:

FLDQVPYSV (SEQ ID NO:63) from gp100;

ILDQVPFSV (SEQ ID NO:66) from gp100; or

IMDQVPFSV (SEQ ID NO:67) from gp100.

31. The kit of claim 26, wherein the synthetic peptides comprise one of the following superagonist peptide sequences:

FMHNVPIPYL (SEQ ID NO:69) from HER-2; or

FYANVPSPHL (SEQ ID NO:70) from HER-2.

32. The kit of claim 26, wherein the kit further comprises cytokines for inducing differentiation of bone marrow derived cells into antigen presenting cells in vitro.

33. A composition comprising dendritic cells, wherein the dendritic cells comprise peptide sequences comprising epitopes corresponding to epitopes of at least four of the following six antigens: TRP-2, MAGE-1, HER-2, IL-13 receptor $\alpha 2$, gp100, and AIM2, wherein at least one of the peptide epitopes is a superagonist peptide, and

wherein the dendritic cells acquired the peptide epitopes in vitro by exposure to synthetic peptides comprising the peptide epitopes.

34. A composition comprising a peptide with one of the following sequences:

FMANVAIPHL (SEQ ID NO:68) from HER-2;

FMHNVPIPYL (SEQ ID NO:69) from HER-2; or

FYANVPSPHL (SEQ ID NO:70) from HER-2.

35. The composition of claim 34, wherein the composition is present in an amount sufficient to induce an immune response.

36. A composition comprising dendritic cells, wherein the dendritic cells comprise a peptide epitope with one of the following amino acid sequences:

FMANVAIPHL (SEQ ID NO:68) from HER-2;

FMHNVPIPYL (SEQ ID NO:69) from HER-2; or

FYANVPSPHL (SEQ ID NO:70) from HER-2.

36. A method for treating a cancer in a patient, the method comprising:

administering to the patient a composition comprising dendritic cells, wherein the dendritic cells comprise a superagonist peptide with one of the following sequences:

FMANVAIPHL (SEQ ID NO:68) from HER-2;

FMHNVPIPYL (SEQ ID NO:69) from HER-2; or

FYANVPSPHL (SEQ ID NO:70) from HER-2.

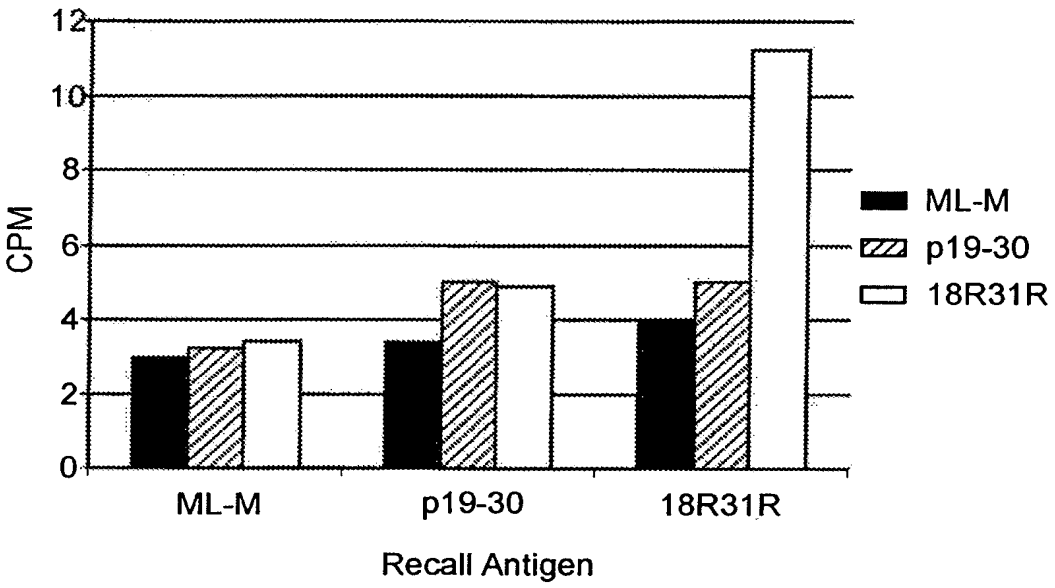

12
10
8
6
4
2
0
CPM
ML-M
p19-30
18R31R
ML-M
p19-30
18R31R
Recall Antigen

FIG. 1

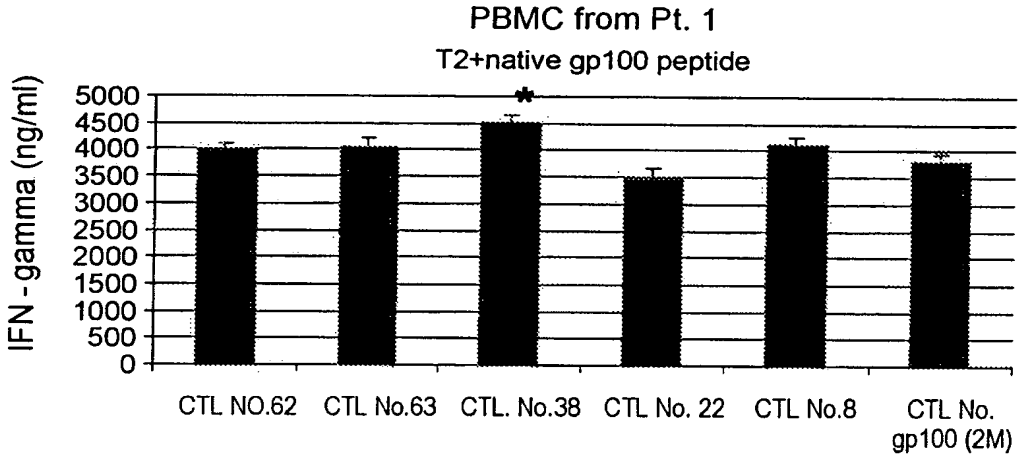

PBMC from Pt. 1
T2+native gp100 peptide
IFN-gamma (ng/ml)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
*
CTL NO.62
CTL No.63
CTL. No.38
CTL No. 22
CTL No.8
CTL No. gp100 (2M)

FIG. 2A

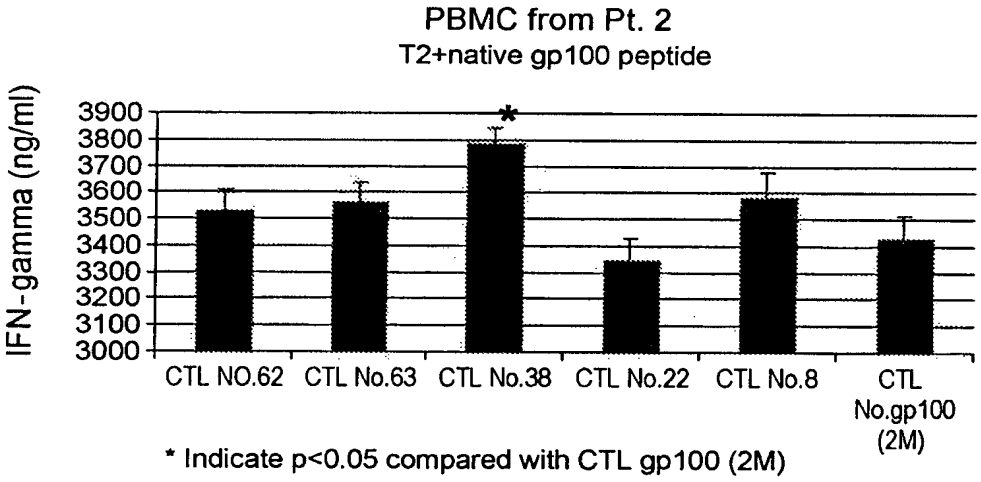

PBMC from Pt. 2
T2+native gp100 peptide
IFN-gamma (ng/ml)
3900
3800
3700
3600
3500
3400
3300
3200
3100
3000
*
CTL NO.62
CTL No.63
CTL No.38
CTL No.22
CTL No.8
CTL No.gp100 (2M)
* Indicate p<0.05 compared with CTL gp100 (2M)

FIG. 2B

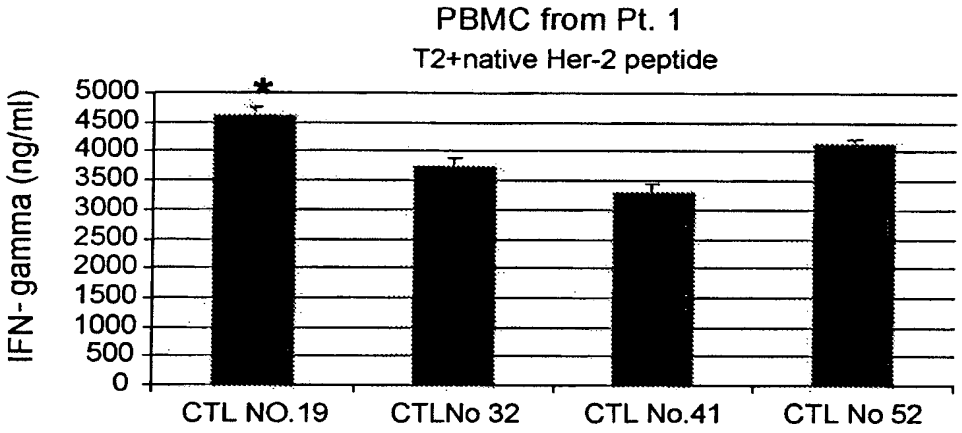
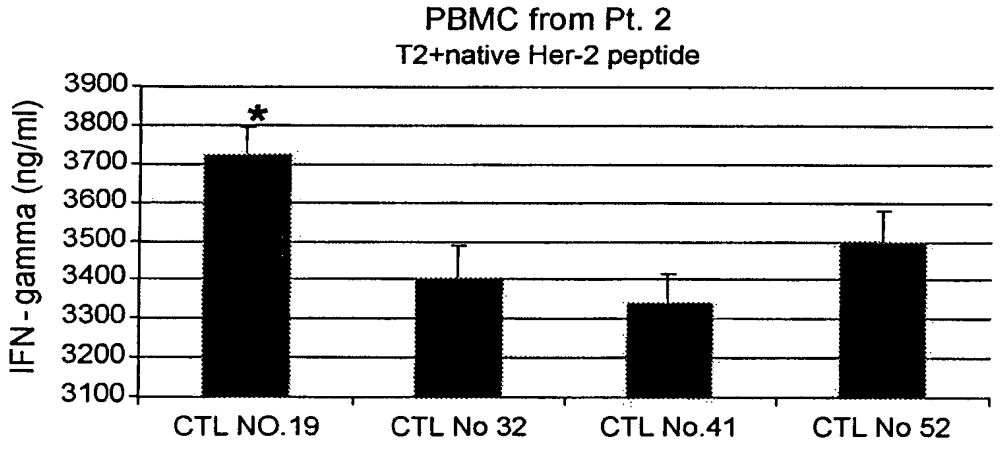


FIG. 3A



* Indicates p<0.05 compared with CTL Her-2 native peptide (No.52)

FIG. 3B

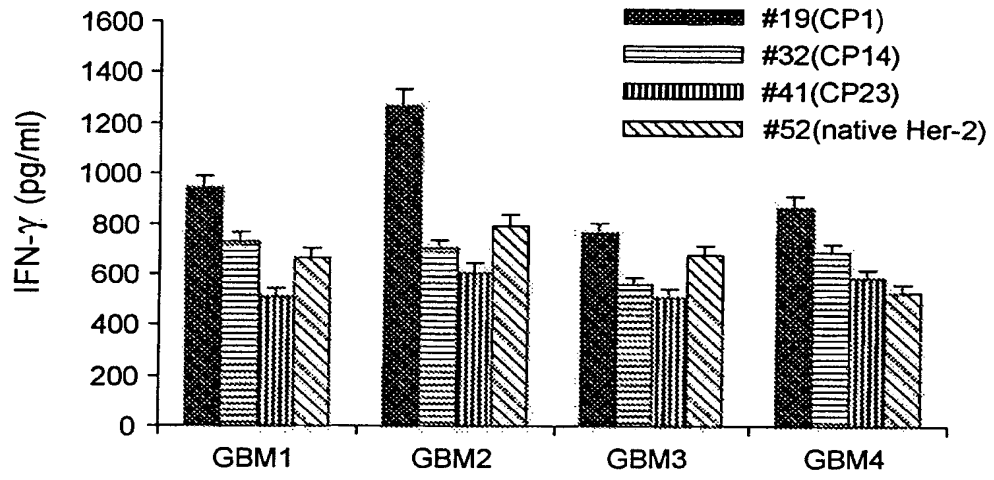

1600
1400
1200
1000
800
600
400
200
0
IFN-γ (pg/ml)
#19(CP1)
#32(CP14)
#41(CP23)
#52(native Her-2)
GBM1
GBM2
GBM3
GBM4

FIG. 4

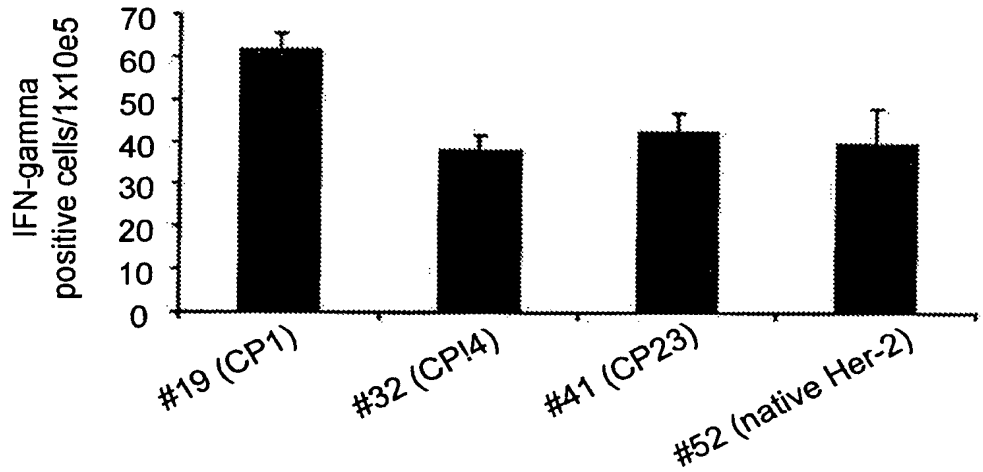

70
60
50
40
30
20
10
0
IFN-gamma positive cells/1x10e5
#19 (CP1)
#32 (CP!4)
#41 (CP23)
#52 (native Her-2)

FIG. 5

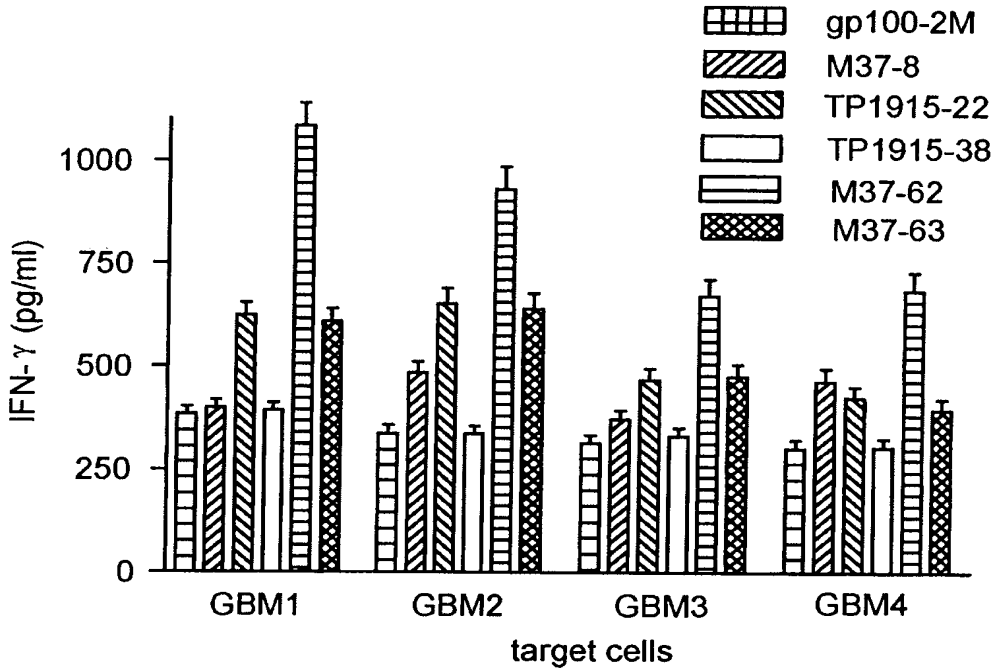

gp100-2M
M37-8
TP1915-22
TP1915-38
M37-62
M37-63
IFN-γ (pg/ml)
1000
750
500
250
0
GBM1
GBM2
GBM3
GBM4
target cells

FIG. 6

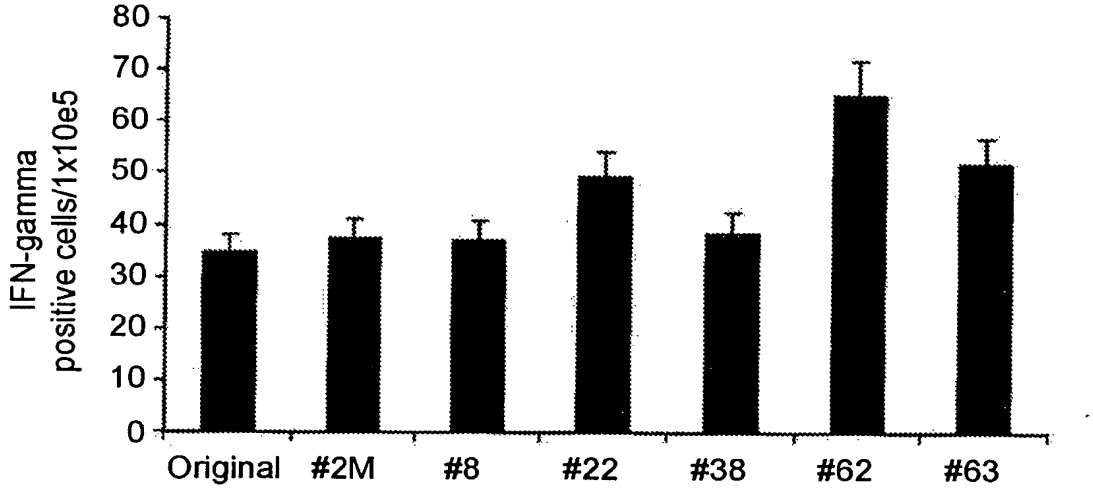

IFN-gamma
positive cells/1x10e5
80
70
60
50
40
30
20
10
0
Original
#2M
#8
#22
#38
#62
#63

FIG. 7

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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(54) Title: CANCER VACCINES AND VACCINATION METHODS

(57) Abstract: Methods and compositions for treating cancers (e.g., neural cancers) by dendritic cell vaccination are provided herein.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US07/79857

A. CLASSIFICATION OF SUBJECT MATTER
IPC: **A61K 35/12**(2006.01),**35/00**(2006.01);**C12N 15/85**(2006.01),**15/86**(2006.01)

USPC: 424/277.1,93.1;435/325
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 424/277.1,93.1; 435/325

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
STN Database, WEST, PUBMED

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WANG et al An effective cancer vaccine modality: lentiviral modification of dendritic cells expressing multiple cancer-specific antigens.Vaccine. 2006 Apr 24,Vol. 24 No. 17, pages 3477-89.	1-36
A	YASUDA et al Dendritic cell-tumor cell hybrids enhance the induction of cytotoxic T lymphocytes against murine colon cancer: a comparative analysis of antigen loading methods for the vaccination of immunotherapeutic dendritic cells. Oncol Rep. 2006 Dec;Vol. 16, No. 6, pages 1317-24.	1-36
A	WEIGEL et al Dendritic cells pulsed or fused with AML cellular antigen provide comparable in vivo antitumor protective responses.Exp Hematol. 2006 Oct;34(10):1403-12.	1-36

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search
16 March 2008 (16.03.2008)

Date of mailing of the international search report
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